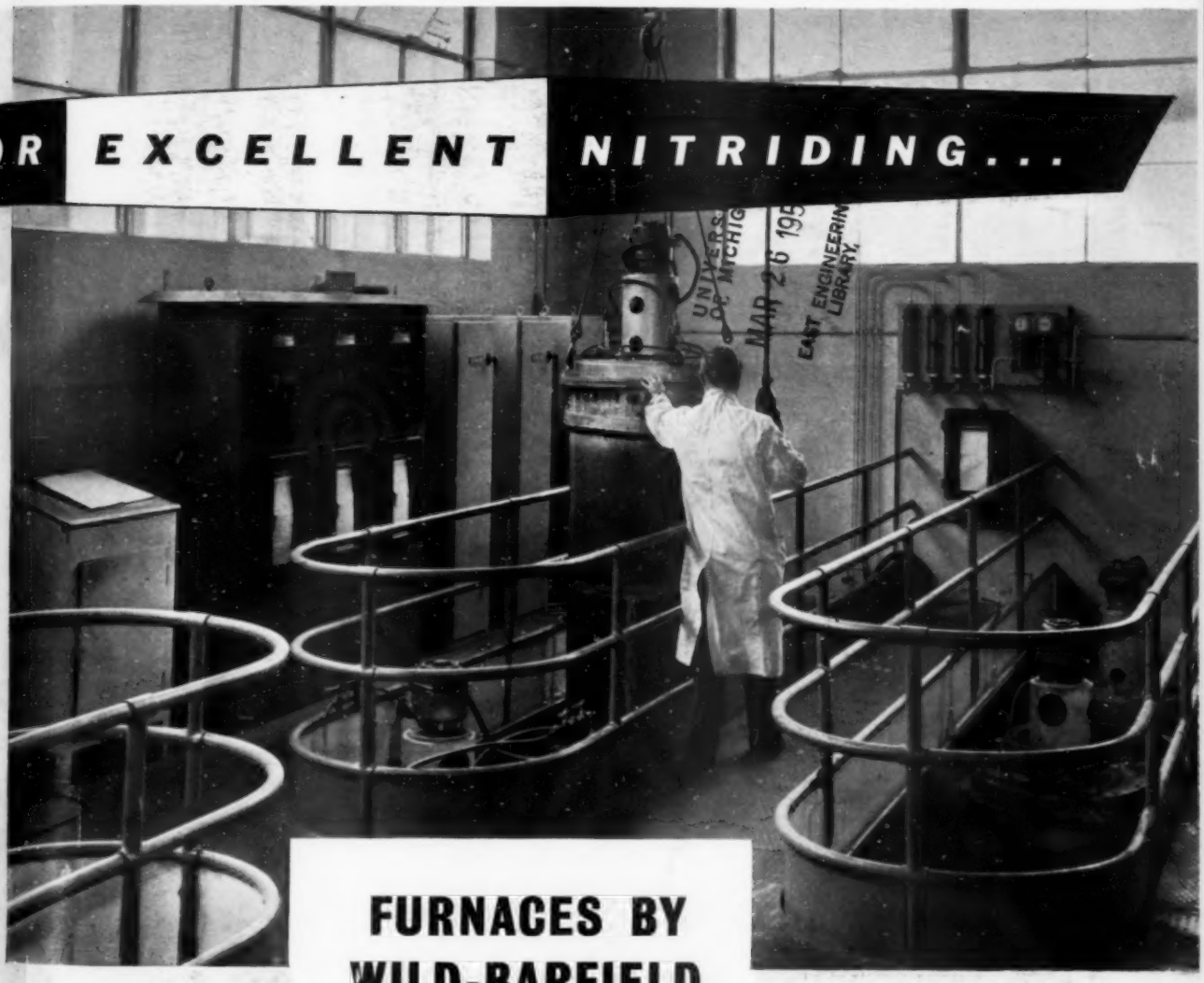
METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 55 No. 329 MARCH, 1957 Monthly: TWO SHILLINGS



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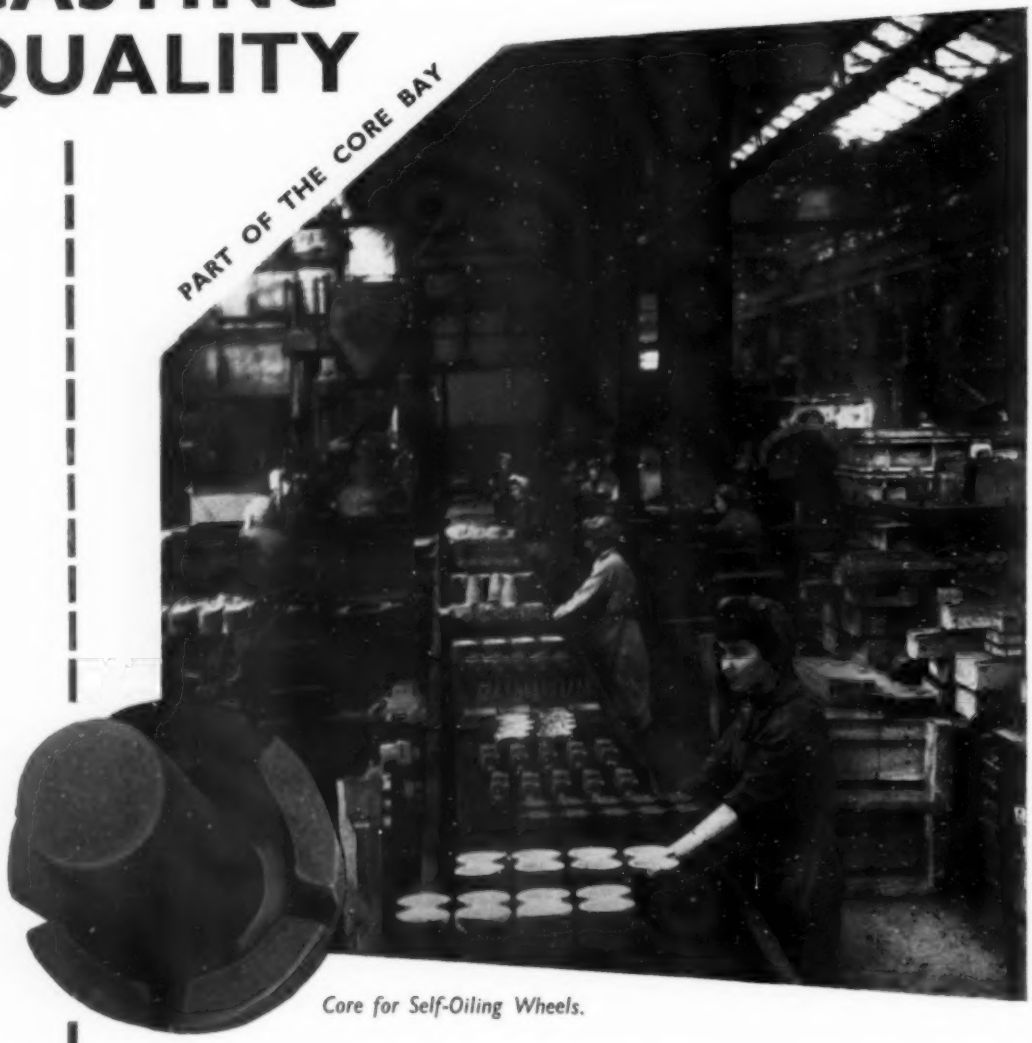

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METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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PUBLISHED MONTHLY BY

The Kennedy Press, Ltd.,
31, King Street West,
Manchester, 3.
Telephone: BLAckfriars 2084

London Office:
50, Temple Chambers,
Temple Avenue, E.C.4.
FLEet Street 8914

CONTRIBUTIONS

Readers are invited to submit articles for publication in the editorial pages: photographs and/or drawings suitable for reproduction are especially welcome. Contributions are paid for at the usual rates. We accept no responsibility in connection with submitted manuscript. All editorial communications should be addressed to The Editor, "Metallurgia," 31, King Street West, Manchester, 3.

SUBSCRIPTIONS

Subscription Rates throughout the World—24/- per annum, Post free.

ADVERTISING

Communications and enquiries should be addressed to the Advertisement Manager at Manchester.

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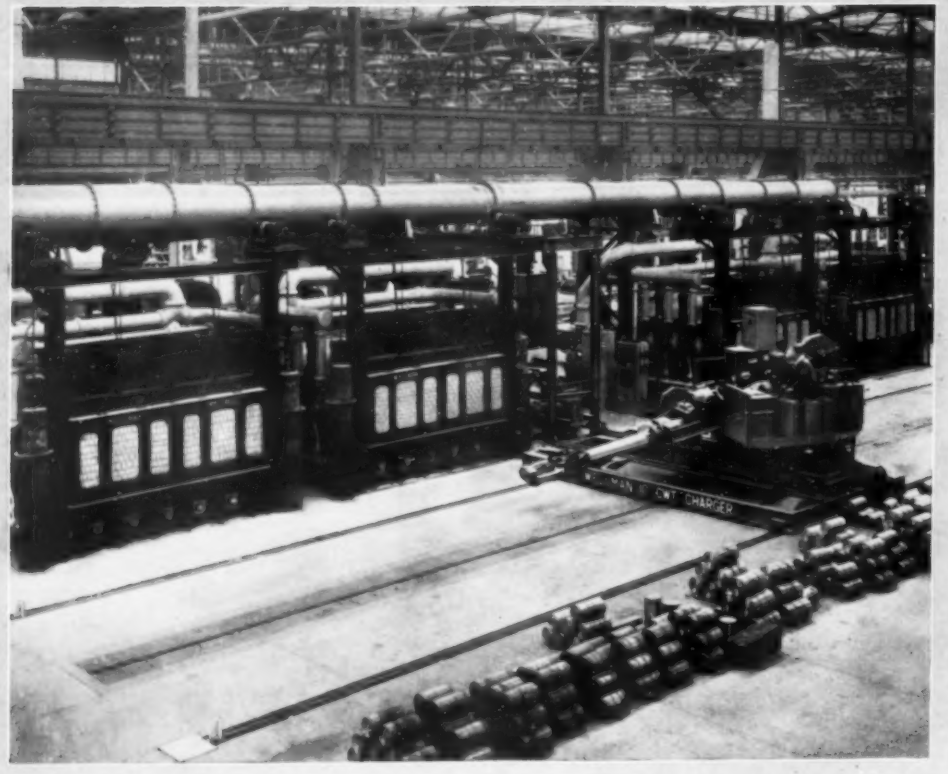

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

MARCH, 1957 Vol. LV. No. 329

Times have Changed

METALLURGISTS who graduated in the late 1920's and early 1930's will no doubt recall that, having graduated, finding employment presented something of a problem, even though the university schools of metallurgy were turning out few graduates each year, compared with the present day. This was mainly due to the economic situation prevailing at the time, with, at its worst, a total of three million unemployed workers. There was too, a certain amount of prejudice against the university man on the shop floor, although he was more readily accepted in the laboratory. In those days, one trailed round the country, attending interviews for this, that or the other job, and, in the end, often had to accept one with a fairly low rate of remuneration.

Contrast this state of affairs with the situation today. Now, instead of the graduate attending a number of works for interview, he just stays put and the personnel officers and staff managers do the travelling, the interviews taking place at the university. He can thus pick and choose—to some extent at any rate—whom he will favour with his services. That competition for graduates is keen is obvious if one studies the "Situations Vacant" columns of both the technical press and a number of the more serious daily newspapers. A further sign of the times is the appearance of a "Directory of Opportunities for Graduates 1957," which gives details of the careers offered by nearly 200 firms recruiting graduates on a large scale, and which is being distributed free to all final year students at universities and colleges in this country. In the preface, Lord Chandos says, "The graduates of our universities are amongst the most treasured assets of the nation. The professions, commerce and industry urgently need their services. Nothing, however, is of greater importance to the individual than that he should follow his bent and choose a career in that part of the field which will give him the greatest interest and the greatest happiness." All this is no doubt true, and when 200 firms are willing to go to the trouble of setting out their wares (in the way of careers) in this manner, the potential graduate can be forgiven if he tends to qualify for the title of "big-head," particularly in the case of the technologist, whose indispensibility to our economic progress—nay, to our economic survival, even—has been so much stressed.

On the other side of the picture, the process of deflation must have been assisted by remarks made at a Schoolmasters Conference in January, by Mr. R. Peddie, Secretary of The United Steel Companies, Ltd., who complained that the universities, particularly the provincial ones, were turning out graduates who had no originality of ideas, very little enterprise, and often very limited ambition. If this is true—and there is no reason why Mr. Peddie should say so if it isn't—it is a most serious matter, for one thing that a university training should do above all else is to help the student to develop his individuality. There used to be a saying that an educated man is a man who "knows what he knows, knows what he doesn't know, and knows where to find what he doesn't know." By such standards these young men are no doubt educated, but industry expects to find more than mere book knowledge in the products of a university. A science graduate entering industry will have studied in the same field as many already in the firm who have followed an apprenticeship and attended technical college courses. In certain specific subjects, his technical knowledge may even be less extensive than that of those who have followed a more specialised part-time course, but his knowledge should be deeper and more balanced, and his trained mind should enable him better to perceive, analyse and apply that knowledge.

In a publication of the Federation of British Industries entitled "A Career for the Graduate in Industry," objection is raised to the conception of "the ladder" of industry, with its implication that anyone can climb it. It is suggested that a better analogy would be a mountain, with the climb broken at intervals by cliffs and chimneys of increasing severity, in that every man has his limitations and some are just not capable of reaching the top, quite apart from the fact that vacancies are fewer on the upper slopes.

The science graduate is initially of value in industry because of his academic knowledge and his ability to use it in industry, which derives more from the teaching and climate of his university career than from learning facts. In its middle and higher ranks, however, industry expects the wisdom and judgment that come from ability to use experience as well as knowledge. Thus, as he progresses to positions of increasing authority, the technical aspects of his training become less important, and the broader qualities of mind and personality more so. As Sir Edward Herbert said at a Conference on Industry and the Universities a few years ago, speaking of the man on the threshold of management, "I believe that his whole future will then turn, not on his specialised knowledge, but on his capacity to assume the major responsibilities of direction and control . . . exercising considerable power . . . wisely and humbly, without himself being corrupted by it."

It follows, therefore, that what a university makes of a man is, in the long run, more important than the knowledge it imparts to him. It seems a little hard, however, to put on the shoulders of the universities all the blame for the state of affairs described by Mr. Peddie. The output of graduates in science and technology has increased considerably in recent years in response to the demands of industry, and the difficulties in staffing have been great. Furthermore, the universities are not responsible for the quality of the raw material they receive—that responsibility must be shared by the schools, the home and, perhaps more than anything, the welfare state mentality, which is the negation of enterprise of any kind.

Meeting Diary

4th March

East Midlands Metallurgical Society. "Recent Developments in Metallography," by DR. D. MCLEAN. Derby and District College of Art, Lecture Theatre, Green Lane. 7.30 p.m.

Society of Instrument Technology, Cheltenham Section. "Ultrasonics," by O. ROBERTS. Rotunda, Cheltenham. 7.30 p.m.

5th March

Institute of Metals, Oxford Local Section. "The Writing of Scientific Papers," by DR. W. HUME-ROTHERY, O.B.E., F.R.S. Cadena Cafe, Cornmarket Street, Oxford. 7 p.m.

Sheffield Metallurgical Association. "Silicate and Alumino Silicate Analysis," by H. BENNETT. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

6th March

Institute of Welding, Manchester and District Branch. "Why Welds Crack," by H. G. VAUGHAN. Reynolds Hall, College of Technology, Manchester. 7.15 p.m.

7th March

Institute of Metal Finishing, North-West Centre. "Modern Painting and Stoving Techniques, including Flow Coatings," by J. J. STORDY and W. G. J. APPLETON. Engineers' Club, Albert Square, Manchester. 7.30 p.m.

Institute of Metals, London Local Section. "Gas in Light Alloys," by DR. C. E. RANSLEY. 17, Belgrave Square, London, S.W.1. 6.30 p.m.

Institution of Production Engineers, Coventry Graduate Section. "Production from Bar Stock," by R. JACKSON. The Craven Arms, High Street, Coventry. 7.15 p.m.

Institution of Production Engineers, London Section. "Recent Developments in Precision Casting," by W. N. JONES. Creed & Co., Ltd., Telegraph House, East Croydon, Surrey. 7 p.m.

Leeds Metallurgical Society. "The Study of Wear and Lubrication Using Radio-Isotopes," by J. B. P. WILLIAMSON. Large Chemistry Lecture Theatre, The University, Leeds, 2. 7.15 p.m.

11th March

Institute of Metals, Scottish Local Section. "Production and Uses of Rare Metals," by DR. J. C. CHASTON. Followed by the Annual General Meeting. Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2. 6.30 p.m.

12th March

Institute of Metals, South Wales Local Section. "Clad Metals," by PROFESSOR A. R. E. SINGER. Department of Metallurgy, University College, Singleton Park, Swansea. 6.45 p.m.

Sheffield Metallurgical Association. "Hot Planetary Mill," by H. M. WALTL. B.I.S.R.A. Laboratories, Hoyle Street Sheffield, 3. 7 p.m.

Society of Instrument Technology, Manchester Section. "The Training of Instrument Engineers," by D. P. LANT. College of Science and Technology, Manchester. 7.30 p.m.

13th March

Institute of Fuel. "The Work of B.C.U.R.A. on the Coking Stoker," by M. V. MURRAY. Institution of Civil Engineers, Great George Street, London, S.W.1. 5.30 p.m.

Institute of Fuel, North-Western Section. "Nuclear Power," by J. M. BAZIN, D.S.O., D.F.C., and R. L. SAGGERS. Engineers' Club, Albert Square, Manchester. 2.30 p.m.

Institute of Physics, Yorkshire Branch. Branch Annual General Meeting, followed by "The Properties of Materials in Nuclear Reactors," by DR. P. MURRAY. University of Sheffield. 5 p.m.

Institution of Production Engineers, Liverpool Section. "Ultrasonic Machining of Hard Materials," by C. F. BROCKLESBY. Radiant House, Bold Street, Liverpool. 7.30 p.m.

Manchester Metallurgical Society. "Precision Casting by the Shaw Process," by N. SHAW. Manchester Room of the Central Library, Manchester. 6.30 p.m.

14th March

Institute of British Foundrymen, Beds./Herts. Section. Lecture by H. W. KEEBLE. Title to be announced later. K. & L. Steelfounders & Engineers, Ltd., Letchworth. 7.30 p.m.

15th March

Manchester Association of Engineers. "Industrial Television," by J. E. M. BRACE. Engineers' Club, Albert Square, Manchester. 6.45 p.m.

Manchester Statistical Society (Economic Statistics Study Group). "Some Aspects of the Steel Industry," by G. DICK. Portico Library, 57, Mosley Street, Manchester. 5.30 p.m.

West of Scotland Iron and Steel Institute. Joint Meeting with the Iron and Steel Institute, Engineers' Group. "A Review of Some Rolling Mill Engineering Practices," by F. G. THOMSON. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

18th March

Institute of Metals, Sheffield Local Section. "Materials of Construction in the Heavy Chemical Industry," by F. H. KEATING. Engineering Lecture Theatre, The University, St. George's Square, Sheffield, 1. 7.30 p.m.

Institution of Production Engineers, Coventry Section. Film Evening—presented by Wickman, Ltd. Films will include such subjects as "Modern Milling Methods" and "The Economic Use of Carbide Tools." Wickman technicians will be in attendance. The Craven Arms, High Street, Coventry. 7 p.m.

19th March

Institute of British Foundrymen, East Anglian Section. "Practical Implications of Research on the Casting of Non-Ferrous Metals," by E. C. MANTLE. Lecture Hall, Public Library, Ipswich. 7.30 p.m.

Institute of British Foundrymen, Slough Section. Film: "Flow of Metal into Moulds." New version introduced by R. W. RUDDLE. Lecture Theatre, High Duty Alloys, Ltd., Slough. 7.30 p.m.

Sheffield Metallurgical Association. "Modern Trends in Iron and Steelmaking Refractories," by DR. H. R. LAHR. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

20th March

Institute of British Foundrymen, Southampton Section. "Latest Developments in Spheroidal-Graphite Iron," by W. W. BRAIDWOOD. Technical College, St. Mary's Street, Southampton. 7.30 p.m.

Institution of Production Engineers, Birmingham Section. Annual General Meeting (members only), followed by "Modern Techniques in Die Casting Practice," by J. BAILEY. Illustrated by coloured sound film. The James Watt Memorial Institute, Great Charles Street, Birmingham. 7 p.m.

21st March

Incorporated Plant Engineers, Merseyside and North Wales Branch. "Welding and Testing of Welds by X-Ray," by R. B. WHALLEY. Stafford Hotel, City Road, Chester. 7.15 p.m.

Institution of Production Engineers, Glasgow Section. "Ferrous Die Casting," by C. A. PAYNE. The Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2. 7.30 p.m.

Institution of Production Engineers, London Section. "Galvanising," by L. F. CHAMBERS and "Metal Spraying," by G. A. CURSON. Also A.G.M. (members only). The Royal Empire Society (Craven Street entrance), Northumberland Avenue, Strand, London, W.C.2. 7 p.m.

Liverpool Metallurgical Society. "Steels at Elevated Temperatures," by J. D. MURRAY. Liverpool Engineering Society, The Temple, Dale Street, Liverpool. 7 p.m.

Society of Chemical Industry Corrosion Group. Symposium on Corrosion of Metals in Buildings: "The Resistance to Corrosion of Non-Ferrous Metals in Buildings," by F. E. JONES; "The Corrosion of Ferrous Metals in Buildings," by J. C. HUDSON and F. WORMWELL; "Corrosion of Metals in Contact with Concrete," by P. E. HALSTEAD; "Aluminium Cladding of Buildings," by E. H. LAITHWAITE and E. W. SKERREY; "The Performance of Zinc and Zinc Coatings in Buildings," by R. W. BAILEY and H. G. RIDGE; and "The Behaviour of Copper in Buildings," by S. BAKER and E. CARR. The Institution of Civil Engineers, Great George Street, London, S.W.1. 9.30 a.m. and 2.30 p.m.

22nd March

North East Coast Institution of Engineers and Shipbuilders. Andrew Laing Lecture. "Structural Steels for Warship-Building with Some Notes on Brittle Fracture," by SIR VICTOR SHEPHEARD, K.C.B. Literary and Philisophical Society's Lecture Theatre, Newcastle upon Tyne. 6.15 p.m.

(*Continued on page 120*)

Copper and Copper Alloys

A Survey of Technical Progress During 1956

By E. Voce, Ph.D., M.Sc., F.I.M.

Copper Development Association

Continued progress has been made in the past year in the metallurgy of copper and its alloys, and in the various sections of this review the author discusses the principal items of interest concerning such aspects as raw material resources, extraction, fabrication, finishing and properties.

DURING the year just ended, the price of copper has fallen sharply and is now at a level which should encourage the wider use of the metal, while providing sufficient incentive for the development of new mining projects. Under such conditions, it can be expected that the production of copper, and its consumption, will tend to increase, to the general benefit of the industry as a whole.

The number and quality of technical publications dealing with copper and copper alloys has been well maintained throughout the period under review, and the present article can do no more than outline a few of those most likely to prove of interest to the reader.

The Production of Copper

Copper Mines and Deposits

References have recently been made to the development of copper mining projects in Eire, Avoca[1-3] being among the localities named. It is said that a joint Irish and Canadian syndicate has obtained parliamentary concessions to work extensive deposits of low-grade ore.

On the Copper Belt of Northern Rhodesia, the hoisting of copper-cobalt ore from the Chibuluma mine at Kalushi has now begun,[4] while at Kansanshi, 100 miles west of Nchanga, the production of copper on a small scale is expected to commence next year.[5] The new Bancroft mine, likely to prove one of the largest on the Copper Belt, is due to come into production early in 1957. Preparations have been long and difficult, and an interesting account of the work accomplished, has been published by Nichols.[6] Lorelei Copper Mines, Ltd.,[7] announce that production of copper has begun at a new mine in South West Africa, the first in this part of the territory. The orebody is being worked by open-cast methods.

Considerable activity is reported from Canada, leading to the possibilities of newly discovered copper-nickel belts near Delahey Lake[8] and at Gogama,[9] both in Ontario, and also in the Sudbury area.[10] Good progress has been made with the Fucunis Lake developments, where a 2,000-ton concentrator is under construction.[11] Additional high-grade ore has been reported on the copper-nickel load at Funter Bay, Alaska.[12] Eco Exploration Co. and New Manitoba Gold Mines have outlined a major deposit of low-grade copper-nickel ore in the Cat Lake region of Manitoba, where a shaft is to be sunk.[13-15] The Eastern Smelting and Refining Corporation propose to establish a smelter and refinery for copper and nickel at Chicoutimi[16, 17]; also in Canada, the Lithium Corporation have undertaking drillings to test for the occurrence of copper and nickel ore.[18]

It is said that the prospecting has substantially increased the ore reserves in the Philippines, and that the capacity of the mill at Toledo, Cebu, is consequently being increased.[19, 20, 21] In Brazil, occurrences of copper and nickel ores have been found at Patos de Minas and Jacupirasga, and the Iguape region, in which the latter is situated, is to be exhaustively examined.[22] A new plant for the smelting and electrolytic refining of copper is being planned by Empresa Nacional de Fundiciones of Chile.[23]

Drillings at Ravensthorpe in Western Australia have revealed a copper ore body with reserves of over 4,000,000 tons, averaging 1·6% copper. A second large ore body has also been located at a lower level, and exploration is in progress with the aim of proving sufficient ore reserves to justify large-scale operations, including the erection of a smelter.[24]

Technical Developments

Since the perfection of the process of leaching with ammonia and precipitation of metallic powders with reducing gases under pressure, considerable activity has been evinced in this field. For example, it is claimed that powdered metals can be produced from a slurry of oxides by treatment with a reducing gas such as hydrogen.[25] Precipitation with hydrogen can be used to separate copper from zinc in ammoniacal solutions of the two metals,[26] while separation from arsenic, antimony, selenium and tellurium can be effected from hot acid solution by means of oxygen under pressure.[27] Copper can, it is said, be extracted from sulphide minerals in ammoniacal ammonium carbonate solutions by passing air or oxygen through them,[28] while the Sill process, which is to be given a production-scale trial,[29] relies on controlled autoclaving of concentrates and the separation of the residue into iron-rich and copper-rich portions. Copper, nickel and cobalt can, moreover, be separated from iron by means of an oxidizing ammoniacal leach, if the concentrate is first roasted to convert the iron sulphide into iron oxide.[30]

According to a recent patent,[31] the acid leaching of sulphide ores, low in arsenic, can be facilitated by a preliminary roasting treatment controlled to leave only sufficient sulphur to form sulphates of the non-ferrous metal values. The roasted material is then given an oxidizing leach in sulphuric acid at about 120°–350° C. under pressure, to form soluble sulphates of the non-ferrous metals. From another source comes the claim that materials containing metallic sulphides, such as ores or concentrates of copper, can be converted to sulphates by roasting in oxygen or oxygen-enriched air, preferably in a closed vessel.[32]

An essentially different approach has been patented by Ansiau[33] for the extraction of copper from residues. He uses the principle that the chloride of the metal is volatile, and that it can be reduced by means of hydrogen under controlled conditions. Moreover, an Indian patent[34] covers the separation of copper alloy scrap into its constituent metals by chlorination at elevated temperatures.

Kellog[35] suggests that equilibrium calculations can serve as a yardstick for roaster-gas composition and sulphate formation in the calcine during fluid-bed roasting practice.

Krivsky[36] has examined the thermodynamics of the copper-iron-sulphur system at the temperatures used in matte smelting, and has measured the activity of sulphur over part of the ternary diagram. From a somewhat different standpoint, Gottardi[37] has studied the effects of heat treatment on composite mattes of copper and nickel, especially in respect of the growth of the various solid phases in the presence of the liquid phase. Yagihashi[38] has discussed the physical chemistry of copper smelting, with particular reference to the reactions between oxygen, hydrogen, sulphur and molten copper.

Refining

Changes made in the electrolytic refining practice of Canadian Copper Refineries, Ltd., between 1949 and 1955 have been ably reviewed by Forbes.[39] He states that no major difficulties have been encountered when operating at high current densities, though the quality of the cathodes so produced is hardly sufficient for direct electric remelting. In this connection, it is interesting to note that a method of removing entrapped sulphate from copper cathodes has been patented.[40] The cathodes are given a brief anodic treatment in water or a dilute electrolyte.

In fire refining, it is claimed that molten copper can be deoxidised and degassed after poling by means of phosphorus or similar additions, and the conductivity afterwards restored by treating with a substance which converts the excess phosphorus into slag. A mixture of quicklime dust with from 10–15% of fluorspar is recommended for the purpose.[41]

Plant Descriptions

Bauld,[42] with others, has written a full description of the electrolytic refinery at Mufulira, the first cathodes from which were produced in 1953, and descriptions have appeared of operations at Chibuluma Mines, Northern Rhodesia,[43] Cerro de Pasco, Peru[44] Copper Cliff, Canada,[45] and Port Kembla, Australia.[46] In more general terms, a publication by O.E.E.C.[47] gives an account of the mining and dressing of low-grade ores in Europe.

Foundry Practice

Melting Equipment

In general reviews of metal melting furnaces, Evans[48] discusses the metallurgical, economic and practical considerations of most types of furnaces normally in use, while Treloar[41] confines attention to those of the low-frequency induction type. Though he covers the ground thoroughly, his paper does not mention an important recent development in this field, namely the coreless mains-frequency furnace, which has been the subject of several publications.[50-55] As it requires no loop of molten metal, it has advantages over the cored type in respect of simplicity of design, and refractory problems are correspondingly diminished.

Moulding Techniques

An exceedingly informative review of the carbon dioxide process has been prepared by Rice,[56] and a critical review of the literature, together with considerable first-hand information, has been published by Schumacher[57], while two discussions have been held in London by the British Cast Iron Research Association. The use of shell moulding at the foundries of A.P.V. Paramount[58] has been described in detail[8]: the castings produced are mainly of stainless steel, though gunmetal is also mentioned. At Victor Products, too, gunmetal is among the alloys cast by this method.[59]

Refractory and plaster mould castings have again been referred to in articles by Street[60] and Mountain,[61] respectively, while the applications of the Shaw process of precision casting have been reviewed.[62] Tin bronzes, brasses and beryllium copper are among the alloys successfully cast by this method.

A sand mould for bronze castings with a high chilling power has been developed by Pell-Walpole.[63] The material is Southport sand mixed with from 15–20% of graphite and 5% linseed oil. Asbestos can be added if desired in order to reduce the chilling power and so to retard solidification in thin sections.

According to Unterweiser,[64] close dimensional tolerances can be maintained in the precision casting of both ferrous and non-ferrous materials, and quick production time is assured by the use of one-piece glass moulds.

Running and Feeding

From experiments on the application of insulated feeding heads to sand castings in gunmetals, Jackson[65] concludes that neither these, nor exothermic feeding devices, are likely to offer advantages in the case of light-section castings, but that they should prove beneficial in dealing with large bronze or gunmetal castings where good feeding is essential. Bunch and Dalbey[66] have also demonstrated the value of insulated sleeves in the feeding of copper alloy castings.

An exceedingly able review of the now copious literature on the running and gating of sand castings has been prepared by Ruddle.[67] An investigation by Hesse, Glassenberg and Baer[68] has confirmed the difficulty of ensuring perfectly sound castings in gunmetal, and recommends gating and feeding methods for minimising micro-porosity.

Degassing and Deoxidation

According to recent trade announcements, a solid degassing agent, based on calcium cyanamide, has been developed.[69, 70] When held beneath the surface of molten copper-base alloys it simultaneously scavenges and deoxidizes the metal.

Neu[71] discusses the technique of producing castings in deoxidized copper of high conductivity, and recommends the addition of a small proportion of phosphor copper, followed by a deoxidant less detrimental to the conductivity, such as calcium boride.

Special Casting Methods

The Asarco process for the continuous casting of copper alloy bars and sections, both solid and hollow, through submerged graphite dies is now said to be producing billets up to 9 in. in diameter and 12 ft. long.[72] A licence has been granted for the operation of this pro-

cess by Enfield Rolling Mills,[73] where castings up to 5 in. in diameter are being made. An important description of the experiments on similar lines which have been conducted at the Tin Research Institute for a number of years has appeared under the authorship of Ellwood, Prytherch and Phelps.[74]

A patent by Junghans[75] claims that folds and similar defects in continuously cast products can be minimised by distributing the flow of metal towards the periphery of the mould cavity by means of a mechanically rotated spout. A good review of continuous casting has been written by Smart.[76]

Willner, Goodman and Tippett[77] describe the production of small ships' propellers in copper-base alloys, among other materials, using an investment casting process. Earlier publications by Barton and Barton on diecasting die design have appeared in the form of a book,[78] and Kopkin and Der Piee[79] have published a bibliography covering 160 references to vacuum melting practice.

Impurities and Porosity in Copper-base Foundry Alloys

Based on an extensive review of literature, and on a questionnaire submitted to the American foundry industry, Versagi[80] has compiled a condensed report on the general effects and means of removal of most of the common impurities met with in copper-base casting alloys. He concludes that refining practice varies widely, and that authentic information concerning the relative effectiveness of the various processes is scanty.

In an article with a strong practical bias, Hinchcliffe[81] gives advice on the production of clean and sound gunmetal castings, laying emphasis on melt quality and on the methods of feeding. More naive is a pronouncement by Daniels[82] on "how to make good test bars" in bronzes and gunmetals. Test bars should be designed so that they are sensitive to melt quality, and should give *poor* results unless the metal is irreproachable.

General Foundry Practice

The attention of readers is directed to a long series of articles by St. John,[83] covering most aspects of American brass and gunmetal foundry practice. The author deals not only with the technical but also with the economic aspects of the industry.

Holmes[84] discusses the sealing of porous castings, and suggests that plastic sealants, because of their greater viscosity, are preferable to metals when dealing with very coarse porosity, whereas metallic sealants are more satisfactory in the case of fine porosity.

The British Standards Institution[85] has issued a glossary of terminology for internal defects in castings, as revealed by radiography, while a general book on foundry practice, both ferrous and non-ferrous, appeared last year.[86]

Fabrication

Furnace Equipment

Jenkins,[87] a specialist in the subject, has reviewed the design of furnaces for heat treatment in special atmospheres. He discusses suitable atmospheres, times and temperatures, and appropriate furnaces for the annealing or heat treatment of brasses, bronzes, cupro-nickels and nickel silvers, among other materials.

The use of low frequency induction heating of billets for extrusion and forging is steadily increasing in popularity. Scovill Manufacturing Co., for example, are operating a three-cell unit of this type for the preheating of brass extrusion billets weighing 110 lb.[88]

Hot Working

Glen[89] recommends chromium carbide dies, containing tungsten carbide and nickel, for the extrusion of brass and copper, claiming that dies of such material maintain their size excellently and are able to withstand high extrusion pressures. According to De Groat,[90] cast beryllium copper dies are eminently suitable for the production of prototype steel forgings as well as for light alloys. Such dies are easy to cast with a good surface, and remain within the required tolerances after a run of some 1,700 steel parts.

A recent article by Cockcroft[91] deals with the fundamentals of hot brass pressing, particularly in closed dies. The author emphasises the importance of flash and thin sections in building up pressure and points out that stresses in the metal should be kept, as far as possible, compressive in character, in order to avoid tearing. He describes how fine cored holes can be produced by means of thin pegs passing through larger pegs which are pushed backwards by the advancing metal.

Rolling

During recent years, much progress has been made in the continuous measurement and control of gauge in the cold rolling of metal strip. The present position has been thoroughly reviewed by Alderton and Hessenberg,[92] and readers are recommended to study their paper for detailed information on this important subject. The pneumatic type of apparatus, of which Alderton and Hessenberg speak highly, has formed the subject of a separate note,[93] while an optical method of measuring and controlling the gauge of wire rod at the exit of hot rolling mills has been described by Gibbs.[94]

Among new developments is the use of nylon rolls, paired with steel, for the roll-forming of sections from pre-finished strip.[95] The nylon rolls act in much the same manner as a rubber punch in presswork operations, and it is claimed that lacquered brass or copper strip can be fed to the rolls without risk of damage to the coating. The National Research and Development Corporation[96] have announced a technique of rolling ultra-thin metal foil by means of equipment which can be used in conjunction with any ordinary rolling mill.

Cold Forming Processes

The 1956 Spring Symposium of the Institute of Metals[97] was devoted to final forming operations, and comprised eight papers on subjects ranging from machining to deep drawing. An important point which emerged from the discussions is that no satisfactory basis for comparing the "workability" of different materials has yet found general acceptance, though several writers and speakers agreed that the quality in question is reflected in the strain-hardening behaviour of the material.

The technique of differential annealing to enhance deep drawing properties was mentioned at the Symposium, and forms the subject of a further publication.[98] The rim of the blank is annealed, while the central portion remains hard and is consequently strong enough to transmit the drawing forces with less fear of fracture around the base of the cup.

The process of metal flow turning is now fairly well known; it is allied to spinning but involves much more displacement of the metal, which can be thinned or even thickened locally if desired. Longley and Hadley[99] have described a number of practical examples with details of speeds, feeds and other operating conditions.

Pelphry[100] describes the application of the allied " Roto-Flo " process to the formation of such items as splines and gear teeth.

Hayes[101] discusses the cold hobbing of dies and moulds from the point of view that there is a direct relationship between hobbing and hardness testing, while Ludington[102] claims that there is a close connection between deep drawing properties and the ordinary tensile strength. It is regrettable that his approach fails to take into consideration the strain hardening properties of the material, which are fundamental in deep drawing, as in all other cold-working processes.

It is interesting to note that a 120-ton press has been installed by the Production Engineering Research Association for the investigation of impact extrusion.[103]

Finishing and Plating

Mechanical Finishing

Two new techniques akin to barrel finishing have been announced. Squibb and Hall[104] have devised a method, which they call " Gyrofinishing," in which the articles to be treated are held stationary while the polishing medium flows over them. This gives greater relative movement between the polishing medium and the work than is obtainable by ordinary barrel finishing, with consequent economy of time. The second of the two processes to which attention is drawn is a combination of barrel and vapour blast finishing.[105] A jet of steam is directed into the barrel above the level of the mixture of chips and parts to be finished, thus applying a vapour blast to the surfaces temporarily and randomly exposed as the barrel rotates. Useful general accounts of normal barrel finishing have been published by Kincaid[106] and by Polucha,[107] and a book devoted to the subject has also appeared.[108]

Electrolytic and Chemical Polishing

For an exceedingly comprehensive review of the development and present position of electrolytic and chemical polishing processes, the reader is recommended to study a recent publication by Jacquet.[109] An almost equally useful review of the patents issued in this field since 1940 has been published by Baur,[110] while Grivel[111] also reviews the subject with particular reference to non-ferrous metals and alloys, including those based on copper.

According to Lorking,[112] the addition of cetyl trimethyl ammonium bromide has beneficial effects on the electropolishing of copper in phosphoric acid, and Cuthbertson[113] mentions that mixtures of phosphoric and chromic acid are preferable to phosphoric acid for the electrolytic polishing of copper and brass.

A recent British patent[114] appears to be generally similar to older techniques developed in America for the chemical polishing of copper, nickel and their alloys. The solutions specified for the purpose contain phosphoric acid, nitric acid, sulphuric acid and water in proportions which can range between wide limits. Stricklen and Gabel[115] refer to a chromate solution of unstated composition which can be used for the chemical polishing of copper, brass and other copper-base alloys. It is said to delay subsequent tarnishing.

Electrodeposition of Copper

As a result of practical experiments, Heiling[116] reached the conclusion that the surface levelling which accompanies the electrodeposition of copper from cyanide baths under conditions of periodic reversal of current is essentially akin to electrolytic polishing during that part of the cycle in which the object being plated becomes the anode. Two patents[117, 118] claim that improved deposits of copper from cyanide baths can be obtained by the use of complex additions, while the use of cystine in acid sulphate electrolytes has been discussed by Sukava and Winkler.[119]

Details of copper plating solutions based on pyrophosphates, as used in America, have been given by Dickenson,[120] while the electrodeposition of fine-grained copper from acid baths containing a thiourea and a safranine or azosafranine has been patented.[121] Lutter[122] has published a useful review of bright copper plating techniques, and Bovet[123] stresses the importance of purity in copper anodes for electroplating.

Fedot'ev and Kruglova[124] have studied the effect of various additions to an acid sulphate bath when backing silver mirrors with electrodeposited copper. They found that Rochelle salt in small quantities was sufficient to prevent peeling of the silver from the glass during deposition of the copper backing. Few readers may be aware of the phenomenally high hardness values sometimes reported for electrodeposited copper ; Fedot'ev and Kruglova record microhardness values comparable with Vickers numbers up to nearly 260, or about double the hardness of the most heavily cold-worked copper ordinarily available.

Electrodeposition of Copper Alloys

As mentioned in earlier surveys, electroplating with tin alloys, including bronzes, is becoming increasingly important, especially as undercoatings for chromium. Price[125] reviews the developments over the past ten years, and a publication by Gore and Lowenheim[126] is in much the same vein. Investigations by Ray, Udupo and Dey[127] on the electrodeposition of brass from copper sulphate baths containing glycerol and sodium zincate have indicated that the process is capable of close control. Hovey, Griffin and Krohn[128] have described an apparatus and procedure for eliminating nodules occurring in previous methods of copper-lead plating. A commutator device converts D.C. into A.C. of special type, and is used in conjunction with a cyanide-tartrate electrolyte.

Coatings on Copper and Copper Alloys

Carlson[129] gives operating details for the electro-tinning of copper wire from stannous fluoborate baths. He claims that deposits are more uniform than those obtained by hot dipping, enabling a saving of two-thirds of the tin to be made.

Two articles[130, 131] give practical advice concerning the electroplating of beryllium copper, including instructions for the preparation of the surface to ensure freedom from beryllium oxide, which would be detrimental to the quality and adherence of the coating. Street[132] has described plating and other finishing processes applicable to gravity die castings in aluminium bronze, which, like beryllium copper, tends to present an oxidised surface.

Reduction plating of copper, brass and bronze with nickel is undoubtedly gaining in popularity. It is said to be cheaper than electroplating, and it is claimed that the coating builds up at a uniform rate, even on intricate parts.[133] A recent patent[134] covers a somewhat similar process for coating copper-base alloys with tin by immersion in an aqueous solution containing an alkali metal cyanide, stannate and hydroxide in specified amounts.

A new technique of metal spraying with oxy-propane nozzles similar to those used for rocket propulsion has been announced.[135] It is stated that the gases reach temperatures up to about 3,000° C., and travel with supersonic velocities. The process has not yet been tried on an industrial scale, but it is claimed to offer considerable advantages over the conventional methods. More novel is a process for coating articles by impacting with metal powder while tumbling in a barrel.[136] A new book by Powell, Campbell and Gouse[137] covers the technique of vapour plating by a variety of methods. An extensive bibliography is appended to each chapter.

In a previous survey, mention was made of a process for the anodic oxidation of copper and certain of its alloys to form an adherent black coating. Hurd, Krieble and Pfeiffer[138] give details of a similar technique which can be operated continuously on copper wire. The coating has a comparatively high electrical resistance, but it is doubtful whether it could be used as a substitute for insulating enamel.

Properties and Applications

The Annealing of Copper

As the annealing of copper wire is of much industrial importance, several recent publications on the subject are worth note. Yokelson and Balicki[139] have established extensive data on the work-hardening and annealing characteristics of five commercial brands of high conductivity copper. A German publication [140] is somewhat similar in scope, though it includes an assessment of the effects of impurities upon annealing characteristics. The annealing of copper wire at the comparatively low temperatures required for the simultaneous baking of enamel sometimes presents a problem, to which both Nielsen[141] and Glander [142] refer. Glander is concerned specifically with various tests for residual stiffness and resilience. A Belgian patent[143] claims that the addition of a small quantity of lead to electrolytic copper tends to reduce the recrystallisation temperature, and so to facilitate the softening of enamelled wire.

Creep of Copper

Two valuable papers on the creep of copper have recently appeared, namely that of Tietz and Dorn,[144] who studied OFHC at temperatures between 75° and 200° C., and that of Johnson, Henderson and Mathur,[145] who examined the creep fracture of copper under various combinations of stress. All the fractures were mainly intercrystalline, and the authors conclude that the hypothesis that intercrystalline fractures arise from triaxial (" hydrostatic ") stresses is untenable for copper at 250° C.

Fatigue Properties

Thompson, Wadsworth and Louat[146] report that fatigue cracks in copper start in slip bands inside an individual grain ; they also confirm that fatigue life can be increased by preventing access of oxygen to the surface. It appears that work is in progress at the Clarendon Laboratory, Oxford, on the fatigue properties of copper at temperatures down to about 4° K. (−269° C.)[147] The results indicate that endurance is markedly improved as the temperature is reduced.

Brown and Lane[148] have investigated the effect of the distribution of α and β in a 60 : 40 brass containing a little tin on the fatigue and stress-rupture properties at temperatures up to 370° C. They found that the tensile fatigue and stress-rupture properties were not affected in the same way by the dispersion of α in the β matrix.

In a contribution to the International Conference on Fatigue of Metals held in 1956 by the Institution of Mechanical Engineers, McKeown[149] has reviewed the available information on the fatigue characteristics of copper alloys, among other materials.

Phosphor Bronze.

The results of what must rank as one of the most thorough investigations of the properties of a limited class of alloys has become available.[150] The authors, Gohn, Guerard and Freynik, give very extensive data on the properties of phosphor bronzes in the form of rolled strip. The publication contains nearly a hundred diagrams and numerous tables of data.

A grade of phosphor bronze of controlled fine grain size is now obtainable commercially in the United States.[151]

Bending Properties of Brasses

Using a simple device, Thelin and Abbott[152] have assessed the relative bending characteristics of 70 : 30 brass wire under various conditions. The best results were obtained with cartridge brass having an average grain size of about 0·05 mm.

New Alloys

Though a considerable number of new or modified alloys have been announced recently, lack of space forbids more than brief mention of certain among them.

In a previous survey, reference was made to the high damping capacity of certain copper-manganese alloys. A further publication[153] discussing the mechanical properties, fabricating characteristics and potential applications of such materials has appeared. The copper-manganese-nickel series of alloys, which can be hardened by heat treatment, have been the subject of further investigation by Dahl and Dreyer,[154] who support the view that the changes are brought about by an ordering process. Quaternary alloys of copper with nickel, chromium and aluminium have been developed for resistance wires. One such material has been the subject of examination at the National Physical Laboratory.[155] It appears that the resistivity is three times that of manganin.

Two complex copper alloys, claimed to have high strength, have been patented in Japan. One of these[156] is based on the copper-manganese-nickel system ; the other [157] is an aluminium bronze containing small additions of cobalt and phosphorus. Good precipitation hardening properties are claimed for this material.

Brunhuber[158] claims that good chill castings can be made from gunmetal containing silicon and manganese, while Hehner, McCurdy and Edelman[159] have shown that satisfactory castings of copper containing 5·8% of titanium can be made by melting in air. The authors give the solid solubility of titanium in copper as 6·0% at 885° C., falling to 0·5% at room temperature, and report good response to precipitation hardening.

Applications

According to a patent by Hunt,[160] complex aluminium bronzes containing iron, nickel and manganese, can be satisfactorily used for piston rings. Details of the properties of a type of aluminium bronze suitable for press tools have been published by Jones.[161]

Advantages in cost due to easy casting are associated

with the use of heat-treated beryllium copper for forging dies.[162, 163] A somewhat similar application of beryllium copper, which is becoming increasingly popular, is for the tips of the plungers of die-casting machines, particularly those producing zinc or aluminium alloy castings.[164, 165]

Carlson,[166] has published annotated tables giving data and American specifications concerning various copper-base alloys for use as spring materials, while Mason[167] has provided comparable information for Bourdon tubes in phosphor bronze and beryllium copper, among other materials.

Corrosion

Stress Corrosion

It has been alleged that the addition of approximately 1% of silicon to brass diminishes susceptibility to stress-corrosion cracking. Steinle[168] discusses the matter in connection with the evaporators of refrigerators, and suggests that such silicon addition is effective in brasses containing upwards of 76% copper.

Continuing earlier work on the stress corrosion of α-brass in ammonia vapour, Aebi[169] has studied the kinetics of crack formation. Logan[170] has used X-ray diffraction methods to examine the orientation of crystallographic planes bounding intercrystalline stress-corrosion cracks in large-grained α-brasses and also those followed by transcrystalline stress-corrosion cracks in large grained β-brass. In research of an equally academic nature, Bakish and Robertson[171] have measured the galvanic potentials of grains and grain boundaries in copper, brasses and copper-gold alloys, in aqueous solutions of both ferric chloride and ammonia. They found that the measured potentials could be correlated directly with the susceptibility to stress-corrosion cracking.

Two German publications[172, 173] also deal with stress corrosion, using copper-gold and copper-zinc alloys. In both systems the maximum effect of mercury in weakening the grain boundaries occurs at 50 at. — % of gold or zinc. In contrast, chemical reagents show maximum reactivity with 20–25 at. — % of gold or zinc, their effect disappearing at 50 at. — %.

Industrial Corrosion Problems

An informative paper by Mason[174] records experiences in the selection of materials for petroleum refinery applications, and tabulates the results of corrosion tests in a wide range of plant locations. Somewhat similar in scope is a publication by Rust [175] describing corrosion problems on the Texas Gulf coast, where the warmth of the sea water is such that corrosion control becomes imperative. The paper is worthy of close study, for it contains numerous hints based on practical experience.

The title of a paper by Breckon and Baines[176] refers to the significance of "minor factors" affecting the corrosion of condenser and cooler tubes. This is misleading, for the article is, in fact, a good review of such important aspects of corrosion as dezincification, impingement attack, deposit attack and stress corrosion. Maurin[177] gives an account of successful anti-corrosion measures applied to cupro-nickel condenser tubes fed with polluted sea water.

Common causes of corrosion failures of non-ferrous metals in heating systems and their ancillary cold water supply pipes have been summarised by Campbell,[178] while Ash[179] gives the results of tests to determine the corrosive and erosive effects of mine waters on materials for mine pumping equipment and drainage. Coit[180] has examined corrosion by exhaust gases from the point of view of the condensation of acidic sulphur compounds, and a good review of corrosion by flue-gas condensates has been written by Kear.[181]

A fairly wide enquiry concerning the incidence of failures of copper-sheathed immersion heaters has been embodied in a report by Thomas,[182] but no very clear-cut conclusions were reached. On the whole, the incidence of failures seemed to be greater in hard than in soft water districts.

Corrosion of Aluminium Bronze by Hydrofluoric Acid

Faced with the failure of an aluminium bronze nut due to penetrative corrosion by hydrofluoric acid, Schussler and Napolitan[183] carried out a series of experiments on material of several different compositions after various heat treatments. Alloys consisting of the α-phase alone were not appreciably attacked by hydrofluoric acid, but penetrative corrosion occurred in cases where either the acicular type of β or the $\alpha + \gamma_2$ eutectoid was present.

Galvanic Effect of Titanium

A brief report[184] indicates that copper-base alloys, including Monel, are among those which should be protected from direct contact with titanium if galvanic corrosion is to be avoided.

Protection

Paul[185] has carried out a systematic investigation of the use of vapour-phase inhibitors for protection against atmospheric corrosion and tarnishing. In the case of copper, brass and bronze, the use of such inhibitors in gaseous form was not particularly effective.

According to Roberti,[186] the corrosion of stainless steels for ammonium sulphate crystallisers can be inhibited by the addition of small quantities of copper sulphate, together with potassium dichromate and hydrogen peroxide, to the liquor.

Oxidation at Elevated Temperatures

Lohberg and Wolstein[187] have studied the oxidation of copper sheet at 400° C., and found marked dependence of the rate of oxidation on the degree of cold rolling. The parabolic rate law of oxidation was followed by heavily cold-rolled sheet, but not by lightly deformed material. The oxidation of OFHC copper to cuprous oxide has been investigated by Baur, Bridges and Fassell[188] at a range of temperatures and pressures. They give photomicrographs showing the growth of the oxide film.

Joining

Gas-shielded Arc Welding

It appears that carbon dioxide is now being used on a production basis as a shielding gas in the United States. Tuthill[189] describes the process in relation to the welding of mild steel, and claims that it is also applicable to copper alloys.

Two patents refer to the gas-shielded arc welding of copper and copper alloys with consumable and non-consumable electrodes, respectively. The first of these[190] deals with a filler rod consisting of copper containing small quantities of titanium, aluminium and/or magnesium, while the second[191] covers a thoria-coated tungsten electrode which is said to produce welds uncontaminated with tungsten when using a shield of nitrogen. A novel alloy for brazing under an inert atmosphere consists of copper with between 25 and 35% manganese, up to 10% aluminium and up to 2% silicon.[192]

For the welding of 90 : 10 and 70 : 30 cupro-nickels by the inert-gas-shielded arc process, Hawthorne and Burth[193] recommend a cupro-nickel filler rod containing about 68% copper with small quantities of titanium, silicon, manganese and aluminium. A recent patent also recommends the addition of aluminium, with or without titanium, to cupro-nickel filler rods for the arc welding of similar alloys,[194] while another[195] advocates additions of iron, manganese and silicon, with complex flux coatings, to cupro-nickel welding rods.

Cook and Stavish[196] describe techniques suitable for joining aluminium to copper busbars. The copper is first covered with a layer of silver solder; procedure is then similar to that normally employed in the inert-gas-shielded arc welding of aluminium. It is stated[197] that industrial diamonds can be inductor-brazed into tool cavities using a silver-copper solder, with hydrogen or nitrogen as a shield and titanium hydride as a wetting agent. In more general terms Hackman[198] has reviewed spot welding by the consumable electrode shielded-arc technique, and Heim[199] has discussed such processes in relation to the welding of brass.

Welding of Heat Exchanger Tubes

During recent years there has been an increasing tendency to replace the rolling of tubes into the tube plates of heat exchangers by welding. The idea has been exploited particularly in the oil refining industry, and also to some extent in marine engineering; a symposium in which the experiences of users and suppliers were exchanged has been held.[200]

Copper-Phosphide Brazing Solders

The properties of a range of commercial copper-silver-phosphorus brazing alloys have been examined by Weigert.[201] The author gives ternary diagrams showing the shear strength and ductility as functions of the content of copper, silver and copper phosphide. Because of its brittleness, the copper-copper phosphide eutectic alloy is difficult to produce in the form of welding rods. A recent patent[202] claims to overcome this drawback by enclosing the pulverised or granular eutectic alloy in a tubular sheath of more ductile material, such as silver solder.

The Strength of Brazed Joints

Hansel[203] reports a series of tests on a hardenable ferritic steel brazed with two silver solders and with copper. All the mechanical properties of the joints, including resistance to fatigue, were considerably better for copper than for the silver solders. In a somewhat similar investigation, Grassi, Cornet and Berger[204] brazed several plain carbon steels with copper and with silver, both being in a pure condition. In the case of the copper-brazed joints it was found that the shear strength depends significantly on design, but that grain size has little effect.

Solid-state Bonding

In two papers,[205, 206] Barnes has reviewed the progress which has been made in the cold pressure-welding of copper and copper alloys, among other materials. Examples include the sealing of tubes and the welding of fine wires to thin tabs, or to certain types of printed circuitry, thus eliminating soldering operations. Storchheim[207] has studied the solid-state bonding of copper to aluminium (and also of aluminium to zirconium) and reports that good results were obtained.

Powder Metallurgy

Production of Rod and Strip

The potentialities of producing wrought metals and alloys from roll-bonded powders have been discussed in several earlier surveys. In the United States, pure copper powder is already being obtained from low-grade scrap on a commercial scale, and sheet, strip, rod and wire are being made from it by roll-bonding. Work, Shaw and Knopp[208] describe the technique.

A British patent of Swiss origin[209] outlines what appears to be a new technique for the production of rod from metal powder. The powder is fed vertically into a tube of dielectric material where it is vibrated to effect consolidation, instead of being pressed. The tube passes through an induction coil where the powder is sintered, and the product is withdrawn by suitable rolls from the bottom. Apparently, the patent is concerned with iron powder, but the technique could doubtless be applied to copper and copper alloys.

Copper-Iron Compacts

Articles produced by powder metallurgy from copper and iron, particularly by the infiltration technique, have achieved considerable industrial importance, largely on account of their ease of manufacture and good mechanical properties. Elliott[210] has discussed the basic metallurgy of the process, and mentions the use of a copper-iron-manganese alloy as infiltrant, instead of copper alone. Another article[211] emphasises the fine dimensional limits to which iron compacts infiltrated with copper can be held in engineering practice, and a patent[212] covers the production of negative electrodes for alkaline storage batteries from sintered copper-iron compacts.

In an elaborate series of experiments, Pelzel[213] has investigated the impregnation of porous iron compacts with molten brass. The addition of up to 1% of aluminium to the brass proved beneficial in minimising the formation of oxides while sintering. Alternatively to direct infiltration of porous iron with molten copper, the copper can be admixed as powder with the iron prior to sintering. Gummeson and Forss[214] have investigated this procedure.

Bushes and Bearings

Mohler[215] attempts to predict the performance of sintered bronze bushes and bearings from the product of the load and speed, whilst Borden[216] describes equipment and methods for the mass production of porous bronze bushes, and discusses costs. For the production of commutator bushes, self-lubricating bearings and similar components, Matsukawa[217] has patented a method of coating graphite with a copper-lead alloy. Hodge[218] proposes the addition of micro-sized pure copper and pure lead particles to regular machine lubricants, claiming that scarred or corroded bearing surfaces are thereby reconditioned.

Other Items

Arthur[219] gives an account of experiments on the hot pressing of copper powders, and differentiates between interconnected and closed porosity. As a result of experiments on four nickel-tin bronzes made by powder metallurgy, Fetz[220] reports that their response to precipitation hardening is inferior to that of similar alloys produced by melting and casting.

An interesting Italian suggestion[221] is that it is possible to produce a hard surface on copper by heating in contact

with copper-beryllium powder, containing about 25% beryllium. The surface layer can be heat treated, and hardness values of over 400 Brinell have been obtained. A general review of powder metallurgy by Morden[222] is appearing in serial form.

Physical Metallurgy

Electrical Properties

Continuing his earlier work on the electrical conductivity of high purity copper alloys made by powder metallurgy, Pawlek, with Reichel,[223] gives plots of the specific resistance against percentage by weight of 16 common elements.

A careful study[224] of the electrical resistance and thermal e.m.f. of copper wires extended in tension at the temperature of liquid helium has shown that no recovery processes occur below 77° K. (−196° C.). Passaglia and Love[225] have determined the electrical resistivities of several alloys of copper and gold at temperatures down to 2° K. (−271° C.), while Pollock and Finch[226] have studied the effects of variations in composition on the electrical properties of Manganin-type alloys.

Other studies of the electrical properties of copper alloys include those of Domenicali and Otter[227] on the thermoelectric power and resistivity of copper-silicon alloys, and of Nishimura and Adachi[228] on similar properties of ternary alloys in the copper-manganese-tin system.

Mechanical Deformation

Lequear and Lubahn[229] have compared creep data with static tensile results for OFHC copper at room temperature, and suggest that the two types of test can be correlated in terms of the increase in stress required to cause a certain increase in strain rate at a given strain. Ebner and Backofen[230] have examined the influence of anisotropy on the cracking of copper under fatigue, while two investigations of the effects of explosive shock on copper and brass, among other metals, have been recorded.[231, 232] By taking sections through impressions made by spherical and conical indenters, Williams and O'Neill[233] have explored the distribution of hardness in the neighbourhood of the indentations.

Though published in America, a paper by Rotherham and Pearson[234] records careful British work on the internal friction and grain boundary viscosity of copper and a number of its binary alloys. Comparable is work by Köster, Bangert and Lang[235] on the damping and shear modulus of tough pitch copper wires after various cold drawing reductions and at a range of temperatures.

Other Physical Properties

Guthrie[236] has determined the electronic specific heat of copper-nickel alloys, while Tucker[237] has usefully summarised the coefficients of thermal expansion for over 50 metals and alloys, including a number based on copper.

The vapour pressure and activity of copper dissolved in molten iron, have formed the subject of two recent publications.[238, 239] The distribution of copper between liquid iron and liquid silver was also investigated and the effects of additions of both carbon and silicon were examined.

Hibbard[240] has studied the relationship between magnetic anisotropy and preferred orientation in wrought magnetic materials, some of which, like Cunife, Cunico and the Heusler alloys are based on copper.

Oxidation at High Pressures

Though much work has already been reported on the oxidation of copper and other metals at elevated temperatures, comparatively little work has been done on the effect of increasing the pressure. An investigation by Baur, Bridges and Fassell[241] is therefore opportune. They found the rate of oxidation of copper to be independent of the oxygen pressure between 1 and 20 atmospheres.

Thermal Treatment and Constitution

Richards, Pugh and Stokes[242] have studied the kinetics of recovery and recrystallisation in copper from measurements of hardness and thermoelectric power. Changes in hardness were taken to indicate the fraction of metal recrystallised, with the thermoelectric power as a manifestation of residual lattice strain, and therefore as a measure of the degree of recovery.

Gruhl and Gumper[243] present a number of pole figures illustrating their experiments on the recrystallization textures of both electrolytic tough pitch and phosphorus deoxidised copper after annealing from various degrees of cold work.

New work[244] has been reported on diffusion in β-brass at temperatures between 500° and 800° C., while the diffusion of copper and zinc in both α and β-brasses has been critically reviewed by Resnick and Balluffi.[245]

Two detailed studies of the transformations occurring in certain aluminium bronzes are those led by Toner[246] and by Thomas,[247] respectively. Both are concerned with alloys near the eutectoid composition. Likewise, two papers have been published by Jaumot and Sawatzky[248, 249] on the alloys of copper with palladium, while the copper-rich portions of two ternary systems have also been investigated, namely the copper-aluminium-indium[250] and the copper-gallium-germanium[251] alloys

Viswanathan[252] has examined the changes which occur in the γ-phase of beryllium copper during heat treatment. He records an intermediate stage which appears to have a tetragonal lattice. The lattice spacings for copper-nickel alloys, among other materials, have been determined by Coles,[253] and the ternary phase diagram for the alloys of copper and germanium and silver has been reviewed by Nowotny and Bachmayer.[254]

Taking special precautions to avoid segregation, Pelzel[255] has determined the solubilities of copper, nickel and cobalt in molten lead. In the case of copper, final solidification occurred at 325·5° C., the solubility being 0·11% at that temperature, increasing to 2·3% at 727° C.

Mention must be made of the revised edition of Haughton's bibliography of alloy systems ;[256] moreover, a new and considerably revised edition of Cottrell's "Theoretical Structural Metallurgy" has appeared.[257]

Inspection, Testing and Analysis

Mechanical Testing

Tests on the deep drawing of steel strip into cups with various diameters relative to the thickness, and also under a range of blank holding pressures, have been undertaken by Wallace[258] in an effort to assess the effect of scale on the cup drawing tests. As the findings are in no way peculiar to steel strip, the results should be of interest to those engaged in the deep drawing of copper and copper alloys.

A report of the International Conference on Hardness Testing held last year at Bremen has been issued.[259] One of the most interesting contributions is that of Bergsman, who shows the superiority of conical over

pyramid indenters, and balls. A book on micro-hardness testing has been published by Mott,[260] while Dervishyan[261] has claimed that there is a more or less linear relationship between the hardness value at the inception of an indentation and any tensile stress simultaneously applied to the specimen.

Metallography

Recently the American Society for Testing Materials has tentatively revised its recommended methods for the determination of grain size. Wyman[262] indicates the improvements in accuracy which are likely to result from the changes. Tests by Worlton[263] indicate that the degree to which ultrasonic vibrations are absorbed in travelling through brass is related not only to the wave length of the vibrations used, but also to the grain size of the brass. On this basis, the author proposes a rapid, automatic, non-destructive method of measuring grain size.

Newly suggested aids to metallography include a polishing machine of which the head is vibrated electromagnetically, giving improved speed and efficiency,[264] a precision universal microscope stage which can be tilted in addition to the normal movements to facilitate the examination of fractured surfaces[265] and a simple oblique illuminator which can be constructed from a piece of Perspex and four small lamp bulbs.[266]

Analysis

New colorimetric methods for the determination of phosphorus[267] and tin [268] in copper alloys have been proposed, and Chew and Lindley[269] have worked out a method for the determination of zinc in copper alloys, based on a chromatographic separation. A polarographic determination of zinc in aluminium bronze has been described.[270]

The technique required for the complete spectrographic analysis of copper alloys in solution has been described by Rouir and Vanbokestal,[271] while Nielsch[272] reviews photometric methods suitable for routine works analysis.

Miscellaneous

While there can be no doubt that the fumes, mainly of oxide, evolved from molten cadmium are injurious to health, the copper industry has always been well aware of the hazard, and accidents are rare. The Industrial Injuries Advisory Council has reported to the Ministry of Pensions and National Insurance on the subject.[273]

The Autumn Meeting of the Institute of Metals took place, last year, in South Western Germany, centred upon Stuttgart and Frankfurt-am-Main. Many works were visited, and descriptions of most of them have since appeared in the technical press.[274]

One of the largest permanent magnets in Great Britain has been installed at St. Andrews University.[275] Materials used in its construction and equipment include copper and brass.

A series of articles by Symonds[276] on metallurgy in music make interesting reading. It is surprising in how large a measure and in how wide a range of fields copper enters into this extensive industry.

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Twin Arc for Foundry Moulding Boxes

To meet the increased demand for all-steel foundry moulding boxes in conjunction with the labour force available, Sterling Foundry Specialities, Ltd., of Jarrow-on-Tyne, are now using the Twin-Arc welding process. This is a manual operation which combines the flexibility of single arc manual welding with the increased speeds of automatic welding. It is of particular use where the expense of automatic equipment is not warranted. Making use of a specially designed Scott-connected transformer, weld metal can be deposited at more than twice the speed of normal manual electrodes with a balanced load on the mains.

With the growth of mechanised foundry practice, accurate manufacture of moulding boxes is essential, and Twin-Arc welding boxes can be made quickly and free from distortion. They are lighter in weight and have a much longer life than the older cast iron type. Their shape and size are not limited by difficulties of casting, and the material can be used to the best advantage with stiffeners in the best positions.

Using Twin-Arc R 6 s.w.g. electrodes, a 25 in. fillet weld took 1 min. 55 sec., as against 4 min. 7 sec. with ordinary hand welding, using 4 s.w.g. single arc electrodes. The time saving of 2 min. 12 sec. allowed for the fact that with twinned electrodes the weld was completed without a stop to change the electrode. The weld profile was also better, with no tendency to undercutting, while root penetration was improved and slag removal was much easier. Quasi-Arc, Ltd., are sole concessionaires for Twin-Arc welding plant manufactured by the General Electric Co., Ltd.

M.P.A. Standards

Recommended procedure for the incoming inspection of ferrite flyback transformer cores has been standardized by the Ferrites Division of the Metal Powder Association and published as M.P.A. Standard 20–56. The new standard sets forth a method of testing ferrite flyback transformer cores. It does not attempt to provide a complete evaluation of the core material, but rather provides a means of unifying the methods of measurement and inspection throughout the ferrite core consuming industry. Test conditions are specified for nickel-zinc ferrites and manganese-zinc ferrites. The method employs a signal generator audio power amplifier and Fluke volt ammeter wattmeter. Copies of the standard may be obtained from the Metal Powder Association, 130 W. 42 St., New York 36, N.Y. at 25 cents per copy.

New Trade Mark

THE name Atomat which has always been associated with the range of Baldwin Nucleonic Thickness Gauges has now been registered as a Trade Mark, No. 755,154. Atomat will apply to Beta, Gamma, Bremsstrahlung and X-Ray Thickness Gauges as well as to the Transverse Profiler.

Meeting Diary

(*Continued from page 108*).

26th March

Institution of Production Engineers, Oxford Section. Annual General Meeting and Film entitled "Metal Spraying." (A.G.M., members only). Education Block, Morris Motors, Ltd., Hollow Way, Cowley, Oxford. 7.30 p.m.

Sheffield Metallurgical Association. "The Technical Press and the Metallurgical Industry," by F. G. MONTFORT-BEBB. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

27th March

Institute of British Foundrymen, London Branch. "Latest Practices in Shell Moulding and Coremaking," by D. H. SCOTT. Constitutional Club, Northumberland Avenue (south-east from Trafalgar Square), London, W.C.2. 7.30 p.m.

Institute of Fuel. Four papers on Dust Deposition and Atmospheric Pollution, by C. J. CRAWSHAW and G. ENGLAND, D. H. LUCAS, W. G. CUMMINGS and W. D. JARVIS and L. G. AUSTIN. Institution of Civil Engineers, Great George Street, London, S.W.1. 5.30 p.m.

Institution of Production Engineers, Worcester Section. Film show—"Steel and Tube Manufacture," by permission of Stewarts and Lloyds, Ltd. Cadena Cafe, Worcester. 7.30 p.m.

Society of Instrument Technology, Chester Section. "The Future of Semi-Conductors in Industry," by D. D. JONES. Board Room of the Chester and District Hospital Committee, 5, Kings Buildings, King Street, Chester. 7 p.m.

28th March

Institution of Engineering Inspection, North-Western Branch. "Thermosetting Phenolic Resins as applied to the Shell Moulding Process," by A. A. LEES. Engineers' Club, Albert Square, Manchester. 7.30 p.m.

Institution of Production Engineers, Southern Section. "CO_2 Process," by DR. D. V. ATTERTON. The Polygon Hotel, Southampton. 7.15 p.m.

29th March

Manchester Association of Engineers. "Nuclear Engineering," by PROFESSOR J. DIAMOND. Engineers' Club, Albert Square, Manchester. 6.30 p.m.

An Investigation of the Structural Conditions in Steel Bearing-Balls

By I. Berz,* B.Sc., A.M.I.E.E., K. F. Hale,† B.Sc., Grad.Inst.P. and C. Wainwright,† M.Sc. A.Inst.P.

Methods are described which are capable of application as non-destructive physical tests of steel bearing balls, viz. a test for strength by spinning in a rapidly rotating magnetic field, a high-frequency electrical test for surface conditions, and an X-ray diffraction examination. The X-ray survey showed the existence of " polar areas " which could be related to residual flow-line markings seen on etched sections. There was also a correlation between the X-ray observations and measurements by the high-frequency electrical method.

It is a natural consequence of the recent development of high-speed engines and compressors that their bearings are subjected to greater loads than has been customary hitherto, a circumstance which has emphasised the desirability of using only components of the first quality. The Research Department of D. Napier and Son, Ltd., has therefore made a survey of non-destructive testing techniques, with the hope that it might serve to extend the scope of testing procedures. In this paper, it is proposed to describe briefly an equipment which is suitable for stressing bearing-balls by spinning them in a rapidly rotating field, and a high-frequency electrical technique which has been used for examining the conditions in their surface layers. A more detailed description will then be given of an X-ray diffraction investigation undertaken at the National Physical Laboratory in connection with the survey, which has shown that variations in grain orientation may exist round the surfaces of bearing-balls. These variations can be related to internal conditions disclosed by the macro-etching of central sections, and consequently to the processes of fabrication of the balls. A correlation is also found between the X-ray diffraction observations and measurements by the high-frequency electrical technique on the same samples.

The work so far done during the survey has been exploratory, and there has been no application of the techniques on the practical scale. Since, however, so far as is known, X-ray diffraction observations of this kind have not been reported before, and in view of the correlation with the other procedures, it is thought that the results are worthy of record. Non-destructive testing methods are also of general importance in connection with industrial processes and their products, and from this point of view the results provide a good example of how a knowledge of the characteristics of an industrial product can be developed by the application of a number of physical tests, each of which is capable of contributing a proportion but not the whole of the relevant information.

The problem of ensuring by means of a testing process that the bearing-balls introduced into a bearing are free from significant faults is an extremely difficult one. The tests that can be applied are limited to those types that do not themselves introduce any blemish into the material. It is also evident, for example, that a surface which is itself flawless may conceal a slight defect in the layers just beneath it, and the problem of discovering such a flaw may be insoluble. In the long run, therefore, high standards in the selection of materials and during the manufacturing stages will remain factors of essential importance, over and above any physical testing methods that may be valuable for the observation of variability of one kind or another.

* Formerly with D. Napier and Son, Ltd. (Now with the National Coal Board).
† National Physical Laboratory.

Mechanical Testing by Means of Rotating Magnetic Fields[1, 2]

Spinning a bearing-ball by means of a rapidly rotating magnetic field is a direct test for strength, since it may be used to introduce high centrifugal stresses without imposing mechanical constraint, and to break up or explode a ball having significant weakness, while leaving a sound ball unharmed in the same conditions of test. The peripheral speeds required to reach the critical condition are of the order of 10^5 cm./sec.

In these experiments, the velocity necessary for critical conditions was reached by accelerating the ball in a rotating magnetic field produced in a stator within which it was located. The rotating field was derived from an oscillator driving a power amplifier which was matched into series and parallel resonance circuits for quadrature fields. The ball was supported on a glass plate with most of its weight balanced by a static divergent field which also provided a radial restoring force. The ball was magnetically coupled to a damping cylinder moving in oil, and damping was critically adjusted to dead-beat conditions. To measure angular velocity, the ball was chemically blackened over half its surface and illuminated, so that the resulting signal from a photo-cell gave frequency in terms of a standard signal which was displayed on the same oscillograph.

This equipment has been shown to operate satisfactorily and $\frac{1}{4}$ in. diameter balls have been run up to a speed of about 1,200,000 revolutions per second. With $\frac{19}{32}$ in. diameter balls, which were employed for the greater part of the X-ray diffraction and electronic comparator work, the maximum speed was about 600,000 revolutions per second, this being only about half the bursting speed. Consequently, it has not been possible to apply this technique as a critical test of the balls that were examined by the other methods, though rotation at about half the bursting speed would be expected to bring to light any mechanical defects in the samples. To increase the rate of rotation of the larger balls would have required primarily an increase in the power-amplifier transformer efficiency at the operating frequency, or a

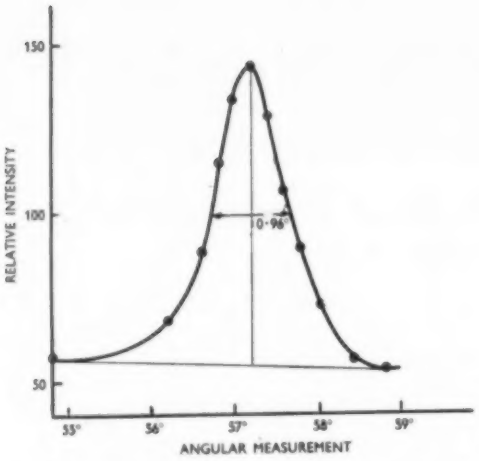

Fig. 1.—Intensity measurements across (110) X-ray diffraction line from hard steel surface. Iron Kα radiation. The half-breadth is 0·96° and is the breadth of the line at half its height.

higher drive efficiency, and this was not possible at the time of the experiments.

Electronic Comparator

Electrical methods with alternating fields make use of the permeability and resistivity of the material under test, but the results are also influenced by mechanical flaws which interfere with the magnetic or electrical flux. The depth of penetration is dependent on the frequency generated by the electrical apparatus, and the observations are influenced by variations in the dimensions of the samples.

In the apparatus used for the present experiments, a frequency of 500 kc./s. was adopted, the depth of penetration into the steel balls being of the order of 0·001 in. The ball being tested was rotated on a turntable of the gramophone type so as to obtain a rapid rotation together with a slower change of axis, thus ensuring that the ball was looked at in all possible ways. Changes in resistivity, permeability, or in physical dimensions, would then alter the characteristics of the oscillatory circuit, resulting in an unbalance which was amplified and displayed on an oscilloscope. Variations between samples were indicated by oscilloscope readings.

X-ray Diffraction Technique

X-ray diffraction methods involve the observation of secondary beams of X-rays that are diffracted at various angles by the crystalline grains of the material being tested. The standard method of operation has been to take a diffraction pattern on a photographic film, the secondary beams appearing as a spectrum of lines. After processing the film, measurements of position may be made and, also, by photometering the distribution of intensity, a line-shape can be obtained. The complete process is a relatively long one, and methods have been developed so that direct readings of intensity can be obtained, using Geiger-Muller counters and electronic circuitry. The process of measurement is thus reduced to a sequence of observations which can be recorded immediately.

This method has been used at the National Physical Laboratory for making rapid surveys over the surfaces of steel samples, and thus deriving information concerning the heat-treatments to which they have previously been subjected, the nature of the constituents of the surface layers, and the condition of the surfaces, after working operations such as grinding or polishing. One such investigation, on the dimensional stability of gauge steel, has already been published[3]; in this case, use was made of the fact that the width of the X-ray lines varies with the hardness, or with the degree of tempering. A typical cross-section of an X-ray diffraction line is shown in Fig. 1. It should be noted that the depth of penetration of the X-ray beam is normally about 0·001 in.

Preliminary Experiments

About two dozen ¼ in. diameter steel balls were withdrawn from stock batches and subjected to X-ray diffraction examination. In order to ensure that all the samples were examined under the same conditions, a small brass cup was fixed at the centre of the spectrometer, and each ball was placed in turn upon its periphery, thus securing identical alignments for all of them. The cup was so arranged that the primary beam of X-rays passed almost tangentially to the ball at the height of its centre, irradiating in this way half of a small cap of the surface. In each case a survey was made of the strong (110) line of the diffraction pattern, and the half-breadth of the curve was measured. The results of the measurements are shown in Fig. 2, together with diamond pyramid hardness measurements made on the same samples.

The half-breadth values form a distributed array, lying, with one exception, between upper and lower limits of 1·00° and 1·40°. The exceptional sample had a half-breadth of only 0·68°, and it was concluded that it would almost certainly prove to be considerably softer than the rest of the batch. Fig. 2 shows, in confirmation of this, that while the bulk of the samples had hardnesses ranging between 920 D.P.H. and 960 D.P.H., the exceptional one gave a value of only 751 D.P.H. It could be concluded that the X-ray diffraction test was capable of sorting out samples whose hardnesses differed markedly from the average. There is also a suggestion of correlation between the half-breadths and hardness values for the general group, that is, a higher hardness tends to be related to a greater half-breadth, and more

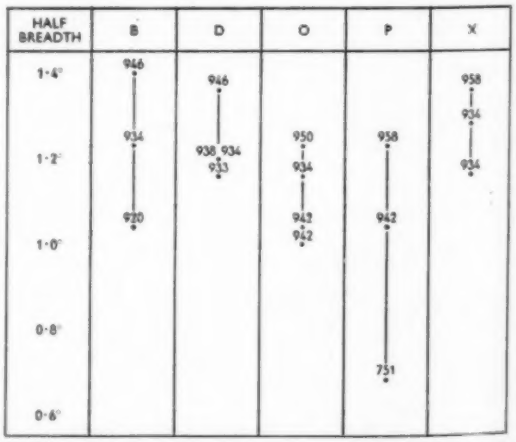

Fig. 2.—Half-breadths of (110) X-ray diffraction lines and corresponding diamond pyramid hardness numbers, arranged in sub-groups.

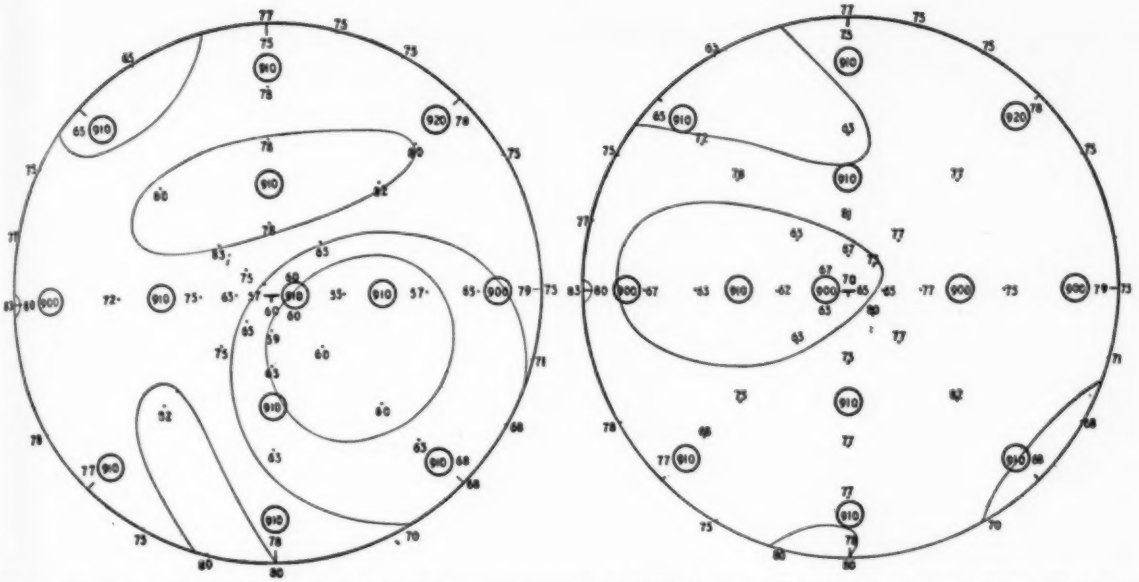

Fig. 3.—Stereographic projections of intensity measurement of (110) X-ray diffraction line on a $\frac{12}{32}$ in. diameter ball (left : upper hemisphere ; right : lower hemisphere). Diamond pyramid hardness values are shown in circles.

particularly so if a comparison is made between members of the sub-groups ; there is then only one instance in which a greater half-breadth corresponds to a lower hardness.

Detailed Survey of Surfaces

In the above experiments, a diffraction curve was obtained for only one position of each ball, which left it uncertain whether the observed differences in half-breadth arose from variations over the surfaces of individual balls, whose average readings would have been more or less the same, or whether the surface of each ball was substantially uniform, with observable differences from ball to ball. To check this, complete surveys were made over the surfaces of a number of balls, and in order to obtain facility in manipulation and to increase the number of measurements that could be made without overlapping of the irradiated areas, balls of rather more than a half-inch in diameter ($\frac{12}{32}$ in.) were now used.

Equipment was set up as before, with a ball resting on the periphery of a cup, and the X-ray beam irradiating a small area as it passed almost tangentially at centre height. Small fiducial marks were put on the surfaces of the samples by means of Indian ink, and then, with the aid of a circular scale below the cup, it was possible to turn a sample so that observations were made on numerous identifiable areas round the spherical surface. In order to make the survey in a reasonable time, the plotting of a complete line-shape for each position of the ball was replaced by a single measurement at the position of maximum intensity of the diffracted beam. Thus, the Geiger-Muller counter tube rested on the spectrometer circle with its entry slit at the position of maximum intensity for the (110) line, and a single reading was obtained for each position of the ball. The observations were made with an initial assumption that although hardness differences would alter the line-shapes, they would not alter their areas to the same extent, so that an increase in width would be accompanied by a more easily measured decrease in height, and vice versa. Fig. 3 shows the stereographic projections of the readings obtained from one sample ; the projections may be considered to represent two hemispheres of the spherical surface, there being a little positional distortion due to the impossibility of depicting a spherical surface with complete accuracy upon a plane. The results show that on the surface of the ball there are two polar areas from which low readings were obtained, surrounded by an equatorial region of high readings, and this result was typical of the readings from all the balls that were examined.

The observations were first considered in terms of hardness variations, but when check measurements were made by plotting complete curves from areas giving high and low readings, the curves proved to be identical in shape, differing only in absolute intensity. Measurements of hardness then showed that each of the balls was uniformly hard over its surface. The next step was to investigate the possibility that the various intensities were due to a preferred orientation of the crystal grains of the material. It is well known that when metals are worked and made to flow plastically by rolling, forging, or similar processes, a rotation of the grains of the material occurs, so that certain planes of atoms of the crystal structure of each grain tend to be in particular directions in relation to the direction of flow. Then, according to the relationship with the direction of an impinging X-ray beam, there will be available more or less than the average number of planes of a given kind to produce the corresponding diffracted beam, which will consequently be more or less intense than for random distribution of the planes.

It is also known that when a bearing-ball is sectioned on an appropriate central plane, and etched, residual flow lines are to be seen which are an indication of the original heavy working of the bar from which the ball was fabricated. In order to discover whether there was a connection between the X-ray observations and such

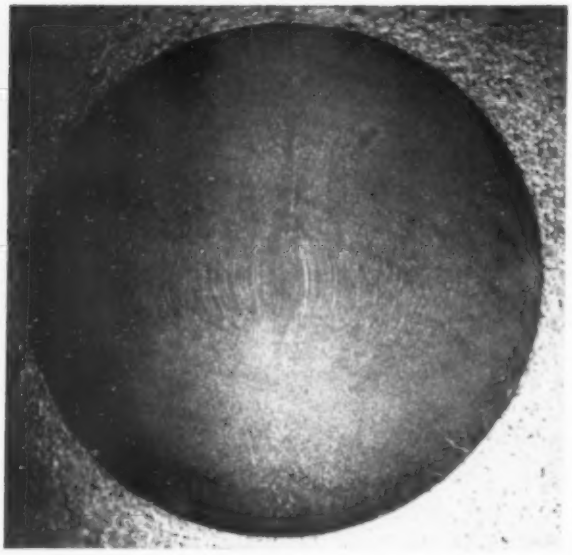

Fig. 4.—Macro-etched section of $\frac{17}{32}$ in. diameter ball, showing residual flow lines.

flow-line phenomena, several samples were sectioned along central planes, so as to obtain from each a hemisphere with its plane face passing through the centres of the low-reading areas defined by a previous X-ray survey, the circumference of the plane face of the hemisphere then containing two diametrically opposed low-reading areas, and two high-reading regions at right angles to them. Fig. 4 shows the etched central plane of the ball which had been used to produce Fig. 3, and its fibre structure is clearly seen. The hemisphere was then replaced on the X-ray spectrometer, with its plane face horizontal, and readings were taken as before round the circumference of the section, when the fibre axis was found to join the low-reading areas, while regions at right angles gave the highest readings. Thus the directional fibre-axis structure within the ball was precisely related to the X-ray observations from the surface.

It was concluded that the grains of these bearing-balls retained directional characteristics which were introduced by the forming processes applied to the bar from which they were made.

Comparison Between X-ray Diffraction and Electronic Comparator Observations

A group of twelve $\frac{17}{32}$ in. balls was subjected to the X-ray test to find whether all of them would display low-reading areas. The first result was the observation that although polar areas were present in all cases, there was a considerable difference in the size of the polar area from one ball to another. There was also a definite tendency for the differences between the low readings at the poles and the high readings at the equator to be greatest when the low-reading areas were large. It was also noted in the samples which were sectioned that a small polar area corresponded to a narrow well-defined polar axis, and a large polar area to a more extensive central region with the fibre-axis characteristics.

The observations are set out in Table I, the polar areas being given the general descriptions large, medium, and small. The actual testing order was that shown by the letters of the first column, but the comparisons are more easily visualised when the results are set out, first in the order of sizes of polar areas, and secondly according to the values of the differences between polar and equatorial readings. In this way, averages can be obtained (column 6) for the small, medium and large area groups. There is clearly a relationship between the descriptive values of the polar areas and the differences between low and high readings.

TABLE I.—COMPARISON OF X-RAY DIFFRACTION AND ELECTRONIC OBSERVATIONS

Ball	Polar Area	X-ray Diffraction		Difference	Average Difference	Electronic Comparator	
		Reading at Poles	Reading at Equator			Reading	Average Reading
G	Small	70	75	5	6·7	1·8	1·8
L	Small	80	85	5		1·5	
A	Small	85	91	6		2·3	
B	Small	77	84	7		1·7	
I	Small	71	79	8		2·0	
K	Small	81	90	9		1·4	
E	Medium	75	84	9	11	2·4	2·7
C	Medium	75	88	13		3·0	
H	Large	70	80	10	12·5	5·2	4·6
F	Large	70	81	11		4·5	
J	Large	75	89	14		4·0	
D	Large	75	90	15		4·7	

In columns 7 and 8 are shown the actual and the average values obtained when these balls were tested in high-frequency equipment of the kind already described. Visual examination suggests that there is a correspondence between the electronic comparator readings and the difference values of column 5, and more precise information has been provided by the Mathematics Division of the National Physical Laboratory, who showed that the probability of this correspondence occurring fortuitously is less than one in a hundred. It is proper to conclude that a real relationship exists.

These observations can be further related to the known variation of permeability with direction within a single crystal of iron or steel. When directional preferences exist in a steel sample so far as the orientation of the grains is concerned, permeability differences should also be expected in proportion to the departure from randomness, with an equivalent influence upon the observations obtained from a high-frequency electrical device. The experimental results from the various techniques are therefore self-consistent.

Acknowledgments

One of us (I.B.) wishes to acknowledge the interest and encouragement of Mr. L. F. Hall, Research Engineer, D. Napier and Son, Ltd., during the progress of the work. This paper is published by permission of D. Napier and Son, Ltd. and of the Director, National Physical Laboratory.

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3 Wainwright, C. and Nickols, L. W. Test for Dimensional Stability of Gauges. *Engineering*, 1951, **171**, 141; *Metallurgia*, 1950, **42**, 401-4.

DUE to the continuing expansion of the company's sales organisation, the North Eastern Area Sales Office of Midland Silicones, Ltd., has been moved from its former address to more extensive premises at 5/7 New York Road, Leeds, 2; telephone: Leeds 26768; telegrams: Midsilicon, Leeds.

General view of the Technical Centre.

New Technical Centre for General Motors

Wide Range of Facilities in Pleasant Surroundings

A TECHNICAL Centre has been opened by General Motors Corporation of Detroit, U.S.A., which affords its technicians and scientists facilities in many fields of activity. Located on a 320-acre site within an area of more than 900 acres, the total building area is 2¼ million sq. ft. The main tower of the building is 132 ft. high, and the 65 ft. high auditorium in the main block consists of an aluminium-sheathed dome of 188 ft. span. Buildings for styling of car bodies, for research on fuel blending, for manufacturing development and for wind tunnel tests taking full-size vehicles are available. The Isotope Research Laboratory has working space for 30 people, and is claimed to be one of the largest privately owned laboratories in the U.S.A. for exploring potential uses of radioactive isotopes in industrial research.

What may now almost be described as a research "city" started in the loft of a barn in Dayton, Ohio in 1909 as a small firm called Dayton Engineering Laboratories Co. (Delco). To-day about 5,000 scientific, technological and administrative staff are employed, their work ranging from pure science and basic research to the more immediately rewarding tasks of developing better materials and designs and better methods of production.

Metal Friction

Amongst the many metallurgical problems being investigated in modern laboratories equipped with the latest equipment are a number concerned with commonplace phenomena, such as the rubbing together of metal surfaces. Virtually every mechanical device has gears, shafts, bearings, sockets or other parts constantly rubbing together. Through long experience with bearings —some of it painful—engineers have learned what types of metals make the best bearing surfaces. By cut-and-try experiments they know which materials will weld or stick—and fail—and which will make durable bearing surfaces. But cut-and-try experience has limits: new bearing problems constantly arise, especially in this high compression and turbine jet era when bearings operate at greater speeds and withstand heavier loads than ever before.

What engineers need is a theory to help them with problems as they arise, so that the time and expense of cut-and-try can be save. In short, it is not enough to know something works well or badly: it is essential to know why it does so. To this end, General Motors research workers carried out an investigation involving 40 different elemental metals, from which two general basic rules emerged.

First, a good pair of bearing metals consists of those metals which have atomic sizes so different that few junctions are formed between them when they are rubbed together. Second, it was found that a good pair of bearing metals occupy special positions on the Periodic Table, which groups all elements according to their chemical and physical characteristics. In effect, this gave bearing designers a sound approach, scientifically bolstered, on which to base their future work. Admittedly this was of great help to General Motors, but, through technical publications, the information was also made freely available to the whole of industry.

Alloy Steels

Such a project personifies the "inquiring mind" at work, and the same type of fundamental research extends to many other fields for the benefit of industry everywhere. Time was when selection of alloy steels for automotive parts was a rule-of-thumb process, more "savvy" than science. As far back as 1937, Research Staff's Metallurgical Engineering Department developed the so-called hardenability test for steel. Later this test permitted successful use of a whole series of low alloy steels that helped conserve strategic alloys during World War II.

Advanced Engineering Development

Another Research Staff mission is advanced engineering development—the long-range development of a

specific product or engineering improvement. For example, because of rapid strides in metallurgy and turbine design during World War II, particularly with aircraft jets, Research Staff decided the gas turbine might have other applications outside the aircraft field. In 1949, a theoretical or " paper study " was made. Next move was to design and build experimental turbine vehicles, using experimental gas turbines. Two engines were developed, GT-302 twin buners for XP-21 Firebird (1953) and GT-300 single burner for a transit bus, the GM Turbocruiser (1954).

These were highly simplified, somewhat oversize units designed to study some basic problems involved in automotive turbines. Results were heartening enough to set the stage for a third unit, GT-304, a regenerative gas turbine somewhat smaller than its predecessors for a second experimental automobile, Firebird II (1955).

Meantime, the question of whether gas turbines will eventually supplant piston engines in automobiles, trucks or buses is still unresolved. Much development work lies ahead, but if and when the time comes to produce turbines, GM's automotive and truck divisions will have Research Staff's experience to draw from.

Stability and Surface Finish

Research facilities and personnel are always ready for trouble shooting assignments when a manufacturing division encounters problems. For example, one day one of GM's diesel divisions reported sticking fuel injectors. X-ray diffraction in Research Staff's Physics and Instrumentation Department revealed that metal in the injector plunger was changing phase, actually " growing " or increasing in volume due to heating in the normal run of service. As is well-known, injector tolerances are extremely fine, measured in millionths of an inch. Any size or volume changes would cause serious sticking whenever those extremely fine parts rubbed together, due to metallic growth. The Centre's Research Staff recommended a change in the heat treatment of injectors during manufacture, and no further sticking was experienced.

In 1952, GM Research Staff, co-operating with one of GM's automotive competitors, developed a so-called " gold standard " for finish standards for metal parts. The project covered seven years of experiments for a set of standards by which any maker of close-fitting engine parts could compare surfaces of bearings, piston pins or cylinder liners.

Need for these standards became apparent during World War II, when surface roughness of manufactured parts varied from shop to shop and industry to industry. When such parts were fitted together in an assembly plant, they sometimes failed in service because their mating or rubbing surfaces were badly matched.

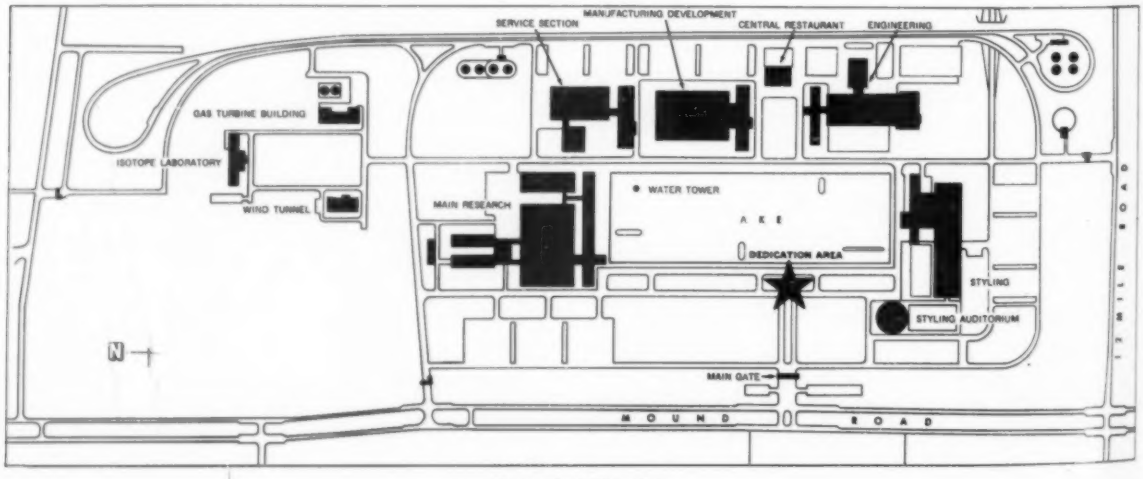
Finally, a set of gold master blocks with varying degrees of surface roughness, measured in millionths of an inch, was produced. Replicas were made from the master blocks, and these can now be used in any shop or plant. Surface finishes can be specified on blueprints. Thus, a manufacturer of bearings in California knows what average surface roughness is needed for his product, which may be used in an engine assembled by a company in Connecticut.

Furthermore, GM Research Staff developed the Surfagage, a precision instrument (now manufactured by a licensee) that gives a shop inspector an instant indication of average surface roughness of machined parts. By running a tiny diamond stylus over the surface of a diesel cylinder liner, for example, the inspector knows immediately whether the liner's average roughness meets specifications. This compact, relatively inexpensive device satisfies industry's long felt need for a surface measuring instrument which has laboratory accuracy, yet is rugged enough for use in the shop.

Research Organisation

Organisationally, Research Staff has 11 departments continuously working on science research, engineering development or miscellaneous large and small service problems.

Departments of the Research Centre listed under the heading of applied sciences are Industrial Hygiene, Physics and Instrumentation, Chemistry, Electro-Chemistry, and Fuels and Lubricants. In the category of engineering research are the following departments: Engineering Mechanics, Metallurgical Engineering, Automotive Engines and Garage, Mechanical Development, Special Problems and Gas Turbines.



Layout of the site.

Each department operates flexibly in that it can call on another department or departments in the care and feeding of a project. As an example of co-operation, the following illustrates how the system works. The Gas Turbine Department took on the assignment of building a series of automotive gas turbine engines. As the project evolved the following combined operations were undertaken. The Special Problems Department supplied its computer service to analyze mathematically various proposed designs, and the Physics and Instrumentation Department developed the starting circuits and controls. The Metallurgical Engineering Department played its part by supplying GMR-235, the high-temperature alloy for the turbine blades; making the castings; and helping in heat treating and welding problems. Special information on lubrication materials for bearings was provided by the Fuels and Lubricants Department, and the Centre's Instrument Service concentrated on special instrumentation problems. The Shop Department, worked on the actual building and fabricating of parts and components. Thus, any story of Research Staff must be related in terms of deeds rather than departments; in projects rather than particular or peculiar specialities.

It can be safely expected that many metallurgical developments will emanate from team work of this kind, backed by great resources which allow work to continue until the target has been reached.

Exhibition of Colour Photographs

Professor Sir Albert Richardson, Past President of the Royal Academy, opened an Exhibition of Colour Photographs—some of the largest ever shown in Europe—at the Tea Centre, Lower Regent Street, London, on January 28th. The Exhibition was sponsored by the *Manchester Guardian* and the photographs, representing Britain's industrial power, were the work of Adolf Morath.

The photographs were made for the purpose of communicating to the world at large what Britain does, and how she does it, and a striking feature of them is the way in which they give the human being visual precedence over the machines. Morath says: "Whenever I go on an industrial assignment I survey not only the machines and installations, but also the human faces, their expressions, movements and rhythms, and combine all that I see, both men and machines, into one complete picture." Organisations for which he has completed assignments include the British Iron and Steel Federation, Esso Petroleum, Kuwait Oil, General Electric, Harland & Woolf, and Selection Trust.

Adolf Morath uses the Agfa Negative Positive process for all his industrial colour photographs. Lighting is by flash bulbs: sometimes up to 50–100 flash bulbs are used for one shot. The two Linhof cameras each have six different lenses of various focal length from extreme wide angle to the longest focus. He has two scientifically equipped colour laboratories in which colour prints up to 20 ft. in size can be made.

Correction

We regret that on page 63 of the February issue, Mr. L. H. Butler, author of the article on "The Effects of Lubricants on the Surface Appearance of Aluminium after Plastic Deformation," was inadvertently described as Lecturer in Engineering, University College, Swansea. Mr. Butler is at University College, Cardiff.

New Inco Film

"Milling and Smelting Sudbury Nickel Ores," the second film in the series produced by the International Nickel Company of Canada, Ltd., dealing with the nickel industry, was publicly shown for the first time in this country on February 7th.

Filmed on location at Copper Cliff and other Company plants in the Sudbury area of Ontario, the 54-minute film depicts the intricate processes by which nickel—and 13 other elements—are extracted from the Sudbury ores. This film, in Eastman colour, covers all the stages in Inco's milling and smelting operations, commencing where the first film in the series, "Mining for Nickel," ended. The new film follows the reduction processes from the time the ore is magnetically separated into massive and disseminated ores until the metals are either shipped to industry or despatched to Inco's refineries.

The film shows the unique processes developed to obtain the greatest yield from the ores, including sintering, flotation, roasting in four-storey high roasters, cooling and oxygen flash smelting. A highlight of the film is a glimpse of the world's largest convertor aisle, where Bessemer convertors work continuously. The intricacies of the oxygen flash smelting furnace are explained in an animated sequence. Developed by Inco engineers, it is a furnace in which copper concentrates smelt themselves. The heat required for smelting is obtained entirely from burning the sulphur and iron in the concentrates with pure oxygen.

Made primarily for showing to a technical audience, the film has the additional purpose of encouraging both high school and university students to consider the exciting career opportunities in the nickel industry. The Mond Nickel Company believes that the films in this series will do much to demonstrate the magnitude of the operations of the nickel industry and the efforts made by the Inco-Mond organisation to maintain and increase nickel production.

A.D.A. Educational Activities

At a meeting of delegates from the international aluminium organisation in Europe—Centre International de Developpement de l'Aluminium—at the headquarters of the Aluminium Development Association, London, the principal item discussed on January 18th was the educational work of the A.D.A., and similar activities undertaken by the other European aluminium interests. A summary of the manner in which the A.D.A. educational services had been built up during the past eight years was given by the Education Officer, Mr. W. Deacon who explained that the Association's work, was aimed at assisting teachers in universities, colleges of technology, technical colleges and secondary schools in giving up-to-date information about aluminium to their respective classes and groups of students. Representatives of the European aluminium industry expressed the view that British activities in this sphere were in advance of many of those carried on elsewhere.

Oil-Fired Melting Furnaces

Factors Governing Fuel Supply Installation

ALTHOUGH the present Suez situation has created a supply problem for users of oil-fired furnaces, there is little doubt that when fuel oil is again available without restriction the trend towards oil firing for many types of furnace will continue. Any detailed planning of a particular fuel oil installation is best carried out in conjunction with the furnace maker and the fuel oil supplier or fuel installation engineer, but there are a number of considerations which are relevant to all installations. These notes are intended to give guidance on these aspects: they are based on information supplied by the Morgan Crucible Co., Ltd., to prospective users of their crucible melting furnaces.

Applicable to any installation of this type are the provisions of B.S.799*, which gives detailed information on all oil burning equipment. It specifies standards which should be met in tanks, pipework, materials, and all the other equipment needed for a fuel oil installation. It also gives standards of installation and testing, and lays down minimum safety requirements.

Grade of Oil

The main grades of oil used for melting are gas oil and the medium and heavy fuel oils. Gas oil (B.S.742 Grade A) can be used for non-ferrous work—providing care is taken not to run the furnace with an excessively high exhaust flame, which results in high fuel consumption. It will also melt cast iron, but at the higher temperatures involved, greater care has to be taken to avoid high fuel consumption. This oil is recommended for aluminium melting and maintaining, and is particularly suitable for maintaining. It generally has a lower sulphur content than the heavier oils, and this may be preferred for metallurgical reasons, in spite of its higher cost. There are also certain applications, such as installations of only one furnace, or where furnaces are used very intermittently, and for aluminium maintaining, where the convenience of using gas oil warrants the higher price of this fuel.

Medium and heavy fuel oils (B.S.742 Grades B, E, F and G), are satisfactory for brass, bronze and cast iron melting; the medium fuel oils in the viscosity range of 200–400 sec. Redwood No. 1 at 100° F., (4·5°–7·0° Engler at 50° C.—230–460 sec. Saybolt Universal at 100° F.) are particularly suitable, and are comparatively easy to handle.

Oil Preheating

Gas oil should not be preheated, but medium and heavy grades of fuel oil are viscous at normal temperatures, and to enable them to be handled satisfactorily and atomised efficiently, it is necessary to reduce their viscosity by heating. If they are not preheated properly, inefficient combustion will result, with adverse effects on furnace performance. Preheating is usually carried out in two stages.

* Obtainable from the British Standards Institution, 2 Park Street, London, W.1. Price 10s.

TABLE I.—STORAGE TEMPERATURES FOR SOME TYPICAL FUEL OILS

Oil Viscosity			Stage 1 Heating (Storage)	
Redwood No. 1 (sec. at 100° F.)	Engler (degrees at 50° C.)	Saybolt Universal (sec. at 100° F.)	° F.	° C.
220	4·5	230	45	8
400	7·0	460	60	16
600	10·0	680	65	19
950	15·0	1,100	75	25
1,500	22·0	1,600	85	30

Stage 1 (*Storage*)—In the storage tank (and also service tank in the case of gravity feed systems) to a minimum temperature that will ensure a homogeneous mixture and proper flow to the pump or line heater.

Stage 2 (*Preheating*)—By line heater to raise the oil to a temperature which will give a viscosity of about 80 sec. Redwood No. 1 (2·7° Engler—92 sec. Saybolt Universal) to secure proper atomisation at the burner.

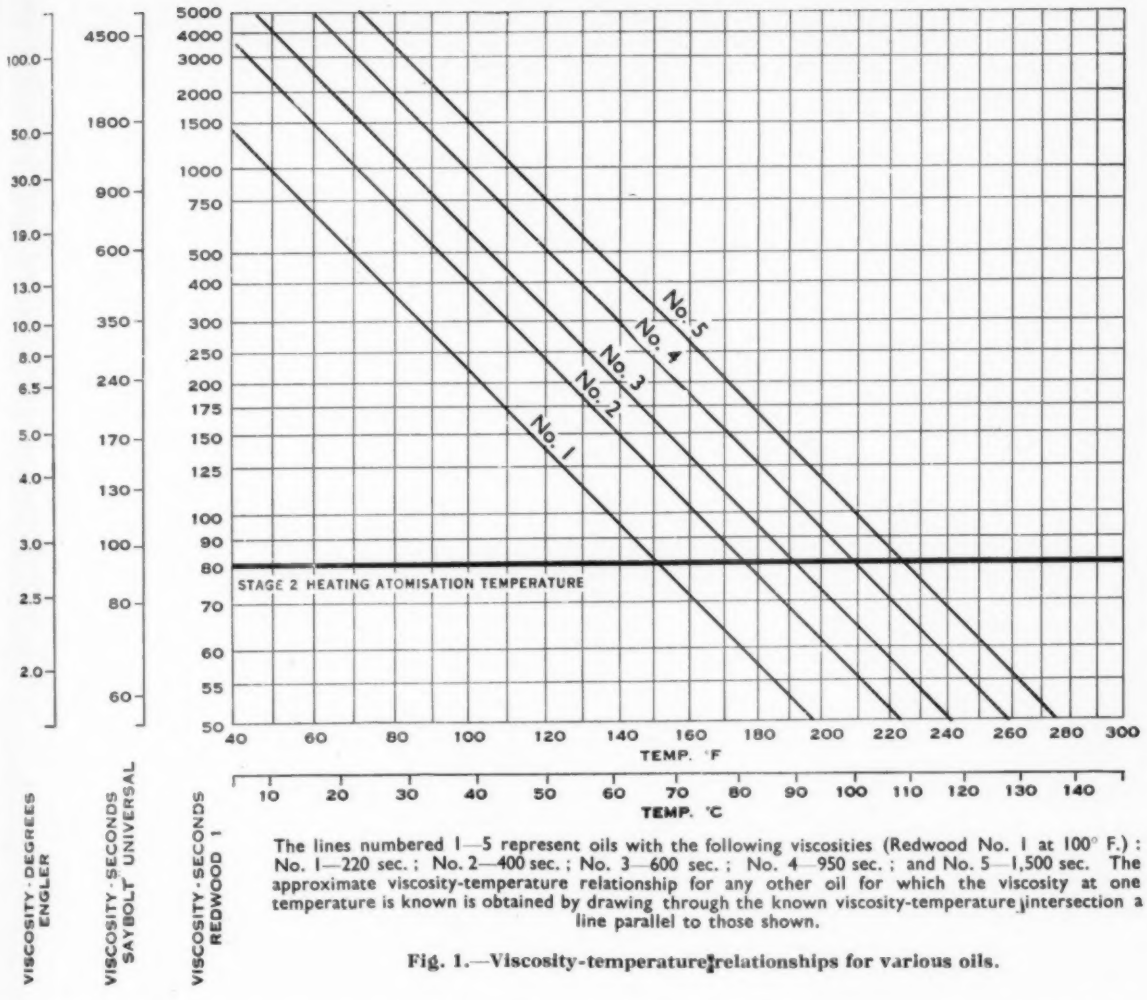
The storage and preheating temperatures depend on the grade of oil. Table I gives approximate storage temperatures of some typical fuel oils. Stage 2 preheating temperatures can be found by reference to the graph in Fig. 1. The lines on the graph represent oils with viscosities ranging from 220–1,500 sec. Redwood No. 1 at 100° F. The approximate viscosity-temperature relationship for any other fuel oil, for which the viscosity at one temperature is known can be determined by drawing through the known viscosity-temperature intersection a line parallel to those shown.

The size of the heater and amount of heating required depends upon the temperature rise and the quantity of oil involved. For Stage 1 heating, consideration must also be given to the size, arrangement and exposure of the tanks, and also the minimum ambient temperature likely to be encountered. In hotter climates, Stage 1 heating is sometimes unnecessary. Given full information, the manufacturer will supply the correct size and type of heater.

Heaters are normally electric, and thermostatically controlled, as over-heating should be avoided. The maximum loading of line heater elements should not exceed 10 W./sq. in. (1·5 W./sq. cm.); for immersion heaters 8 W./sq. in. (1·2 W./sq. cm.)

The line heater in a ring main system is best installed in the pump house. It should be capable of heating the total flow of oil required when all burners are at their maximum, the oil being circulated at the Stage 2 atomisation temperature. It is usual to install heaters in tandem to guard against break-down. For gravity feed systems, the line heater should be positioned near the burner. If desired, one heater can be used for two or three furnaces, providing the branch lines from the heater are kept short.

Where pipe lines from the storage tank are exposed to temperatures below that of the Stage 1 heating temperature, electric pipe heating cables should be clipped to the pipe, in order to maintain the oil at the necessary



The lines numbered 1—5 represent oils with the following viscosities (Redwood No. 1 at 100° F.): No. 1—220 sec.; No. 2—400 sec.; No. 3—600 sec.; No. 4—950 sec.; and No. 5—1,500 sec. The approximate viscosity-temperature relationship for any other oil for which the viscosity at one temperature is known is obtained by drawing through the known viscosity-temperature intersection a line parallel to those shown.

Fig. 1.—Viscosity-temperature relationships for various oils.

temperature. With the heavier grades of oils, it is necessary to fit pipe heating cables throughout the installation in order to keep the oil at the correct temperature. All lines carrying heated oil should be efficiently insulated against heat losses with lagging.

Whenever medium and heavy fuel oils are used, it is necessary to preheat them, no matter what the application. The fuel oil supplier will provide any additional information necessary, and will also confirm the correct heating temperatures for the fuel oil in use.

Fuel Oil Installations

The oil can be supplied to the burner by a pumped ring main system or by gravity. The pumped system is usually considered preferable, because it is clean and neat, and can supply oil to the burner consistently at the correct pressure. Even for small installations, a pumped system is a practical proposition, and often does not cost any more to install than the elevated service tank needed for the gravity feed.

Ring Main System

In a typical ring main system, the oil is drawn from the main storage tank by a motor driven pump and circulated through the oil pipe ring main, round the installation and back to the suction side of the pump. Branch lines are taken from the ring main to the burners.

A pressure of 4–5 lb./sq. in., (0·3–0·35 kg./sq. cm.) is maintained by a pressure-regulating valve fitted in the ring main. The hourly volume of oil circulated should be at least double that of the total maximum required by all burners fed from the system. The branch pipe to each burner should be ½ in. (12·5 mm.) bore; the size of the main depends upon the amount of oil being circulated and length and design of the main. Pumps should be installed in duplicate to guard against break-down.

Gravity Feed System

The oil can be supplied to the burners by gravity from a service tank. The bottom of this tank should be approximately 10 ft. (3 m.) above burner level, in order to give the correct oil pressure at the burner. The down pipe from the tank should be 1½ in. (40 mm.) bore, and the branch line to the burner 1 in. (25 mm.) bore. A number of furnaces can be supplied from one tank, providing the pipe length to the furnace furthest away from the tank is not excessive, so that the furnace is starved of oil. It is not possible to lay down a firm

ruling, as it depends upon the particular lay-out. However, it will generally be found convenient to limit to four the number of furnaces supplied by one tank: these should be grouped together.

The service tank should not exceed 200 gal. (1,000 l.) capacity, and must be so placed that escaping oil cannot reach any surface hot enough to ignite it. Particular care should be taken when siting gas oil tanks.

The oil from one storage tank is pumped up to the service tank by either a hand pump or an electric motor driven pump. In the latter case, automatic filling of the service tank can be arranged by means of a float switch arrangement situated in the service tank, which controls the operation of the motorised pump. When a motor driven pump is used, it is also advisable to fit a hand operated pump as a stand-by. The overflow outlet of the service tank should be connected back to the storage tank.

The total oil storage capacity should be based on the frequency and size of delivery from the fuel supplier, and maximum oil consumption. It is a good plan to have a reserve capacity of at least two weeks' supply at maximum rate of oil consumption. Where the total storage capacity decided upon permits, it is good practice to install two tanks, each sufficiently large to hold at least a complete consignment of oil rather than a tank twice its size. It is then possible to use tanks alternately, the oil being drawn for use from one tank, whilst the other is settling-out.

Safety Devices

Shut-off valves should be fitted in the oil supply lines, so that, in the case of air supply failure, the oil supply to each furnace is automatically shut off. These valves can be of the diaphragm type, actuated by air pressure from the fan, or they can be electrically energised magnetic valves which shut on failure of the power supply. In the former case, the valves shut upon a drop in the air pressure.

World Metallurgical Congress

THE American Society for Metals, sponsor of the 2nd World Metallurgical Congress in Chicago, U.S.A., announces that 450 metallurgists, educationalists, and management, engineering and research executives have already planned to make the overseas trip for the one-week Congress in Chicago, November 2nd to 8th, and the two-week industrial plant tour immediately preceding the Congress.

Overseas conferees will arrive in New York City by October 18th, 1957, where conferences and other meetings will be held preparatory to the planned tours selected by each individual. There will be nine simultaneous two-week study tours of U.S. metal industries covering steel making and refining, non-ferrous refining and fabrication, heat treatment, welding and joining, management problems in the metal industry, research, metal aspects of atomic energy, and inspection and testing. Both the tour and technical sessions in Chicago on inspection and testing will be a part of the 2nd International Conference on Non-Destructive Testing, which will be held at the same time.

No money exchange difficulty will be experienced since all U.S.A. travel and hotel expenses except meals will be handled in advance for each conferee by Thos. Cook and Son and Wagon-Lits Cook. Overseas round trip air or sea travel may also be handled by Thos. Cook and Son if the conferee so desires.

Previous to and during the Congress in Chicago, conferees will have their greatest opportunity for the exchange of ideas and techniques in both metal production and metal fabrications. One example will be a session on the topic of man-made plutonium, until recently held secret by agreement between the governments of the United States, Great Britain and Canada.

All inquiries for further information should be addressed to the American Society for Metals, 7301 Euclid Avenue, Cleveland 3, Ohio, U.S.A.

Successful Gas Exhibition

MORE than 10,000 industrialists visited the "Gas At Work In Industry" Exhibition during its ten-day run, from January 22nd to February 2nd, at the Royal Horticultural Hall, Westminster. The exhibition, as its name implies, showed the part gas plays in industry. Over 500 firm inquiries—claimed as a record for a specialist exhibition of this nature and size—were logged, but the full outcome of the exhibition will not be known for at least two years.

To stage set, in the four days available, this unique exhibition, involved a considerable amount of planning and preparation. The Exhibition Committee (representatives of the North Thames, Southern, South Eastern and Eastern Area Gas Boards—which sponsored the exhibition) worked on the project for six months. Not least of the difficulties was the problem of weight. A webbing of steel girders had to be placed under some of the heavier exhibits in order to distribute the weight, and in places the floor had to be shored up. Special equipment to provide gas, water and air at varying pressures had to be installed in the basement. Such was the detailed planning that a quarter of a mile of piping, prefabricated before the show, was laid in the first half-day of getting into the hall. Each appliance had a scheduled time for arrival and, despite the difficulties created by petrol rationing, was erected and working in time for the Press Pre-view on January 21st.

Errata

WE regret that a number of typographical errors have appeared in recent issues. Readers are asked to make the following corrections.

SOME OBSERVATIONS WITH THE ELECTRIC SPARK MACHINING PROCESS (*December*, 1956)

The next to the last line of column 1, page 265, should read—

the edge of the hole, while slip lines were visible 0·005 in.

NEW BRITISH ANALYTICAL STANDARDS (*January*, 1957)

The 16th line of column 1, page 47, should read—

e.g. 0–0·1%. In both methods the determination is

THE ALUMINIUM SUPPLY POSITION (*February*, 1957)

The 7th line from the bottom of column 2, page 59, should read—

in 144 Soderberg furnaces, each of 40,000 amp. capacity.

Some Notes on Iron and Steel Production in Sweden

By J. Dunning, B.Sc.(Eng.), A.I.M., A.I.Prod.E.

Principal, Cleveland Technical College.

Following a tour of the Swedish iron and steel industry last summer, the author presents some of his impressions and refers to differences in practice in comparison with iron and steel production in the United Kingdom.

THE Swedish iron and steel industry was founded on water power, forests and a wealth of high grade iron ore. Even to-day, the iron and steel companies boast large afforested estates, although these forests no longer supply charcoal for the making of the famous Swedish irons, for, because of labour shortages for charcoal production and competition for the timber, much of the latter is used in the pulp industry.

Sweden has no coal suitable for the manufacture of good metallurgical coke, and it is not surprising, therefore, that fuel is treated with the greatest respect. Economy in fuel and manpower has been one of the principal considerations in the design of the new plant that the Swedish companies are now laying down. It is a claim, and interesting for comparison, that where many countries expend a ton of coke in the production of one ton of pig iron, at Fagersta one ton of coke is used to produce one ton of rolled steel. She has, however, some of the richest ore deposits in the world, and is able to use her ironstone as a bargaining power for the importation of best quality coke. In the Lapland fields, some 2,200 million tons of magnetite ore (up to 70% pure magnetite) are readily available. Although this ore is high in phosphorus content, and not widely used by the Swedish steelmakers, it is a very suitable ore for the Thomas process, and is exported in large quantities to the Ruhr, Britain and the U.S.A.

Ore Supplies and Treatment

Extensive reconstruction at the Loussavaara-Kiirunavaara mines began in 1948 and is expected to be finished by 1962: as a result the annual output of ore at Malmberget and Kiruna will be increased from 8 million to 18 million tons. The five mines at Malmberget have been linked by a 75 mile underground railway system on which electric locomotives pull 250 cars, each car holding 25 tons of ore, which can be bottom emptied in ten seconds. After crushing, the ore is transported to the surface where the concentrate is pelletised. The annual capacity of the pelletising plant, the first in the world on a large scale, is 100,000 tons.

While the ore deposits of Sweden may be divided into two groups, those of Norbotten county, which have already been mentioned, and those of Central Sweden, the latter only accounts for 10% of the estimated reserves. The ores of this region may be divided into two groups, of low and high phosphorus content. The high phosphorus ores, which constitute the majority of the Bergslagen district reserves, are apatite ores with a high iron content (about 60%), and with up to 1% of phosphorus: they are localised in south-east Dalarna, while the low phosphorus ores are scattered throughout the Bergslagen area. The low phosphorus ore of this region falls into one of three main classes, namely quartzitic, skarm and calciferous. The most important group of ores of the quartzitic type are the magnetites and hematites of the Stripa and Norberg fields. These ores are not only exceptionally rich—more than 50% of iron—but also have suitable gangue material in the form of silicates, limestone and quartz, and are notably lacking in phosphorus and sulphur. The mines of Bondgruvan and Kallmora supply the Spannarhuttan blast furnace plant of Surahammar A.B. with ore from the Norberg field, and the largest plant of this region, namely Fagersta, also receives ore from this field. The skarm and calciferous ironstones are not so uniform in iron content as the quartzites, but their phosphorus content is usually lower, and in some cases the ore is almost free from phosphorus.

In contrast to the Dwight-Lloyd process used in this country, the Swedish practice is to use either the Greenawald or Kantorp processes for the sintering of ore fines. The magnetites are so dense that crushing and sintering are necessary in order to impart sufficient porosity for reduction in the blast furnace. At Fagersta, both Greenawald and Kantorp units are in use, the latter consisting of eight pans which revolve under a fixed ignition hood and use down-draught firing. In both these units blast furnace gas is used for firing. As mentioned earlier, the pelletising process is now employed at Malmberget, the iron ore concentrates being formed into pellets of about 1 in. diameter and fired at a temperature of 2,100° F.

Another feature of Swedish iron making is in the desulphurisation of the molten pig iron, immediately after tapping. Desulphurisation is carried out by the Kalling process in which the iron is agitated with burnt lime in rotary receivers. The blast furnace plant at Fagersta, which uses this process of desulphurisation, comprises three blast furnaces coping with 100% sinter burden and producing 150,000 tons of pig iron per year. These furnaces have recently been lined to the bosh with carbon refractories. Air for the furnaces is recuperator-heated and reaches a temperature of 600°C.

Increased Steel Production

In post war years, there has been a great rise in output, mainly in merchantable iron and steel. Three works are mainly responsible for this, namely Domnarvet, Norrbottens Jarnverk and Fagersta: at the Central Swedish factory of Fagersta, ingot capacity has risen by more than 100,000 tons. The important point about

these increases is that they are based on iron derived from ore, and not on an increase in the amount of scrap used.

Increased production has been based on coke pig iron with further processing by the Bessemer plant, or by duplexing in the Bessemer and electric furnace plants. At Fagersta two 20 ton acid-lined converters are used. The blow, which takes twenty minutes, is divided into two stages, one in which the converter is in the normal position and the other, at the beginning of the carbon boil, in which it is partly turned down in order to counteract the low silicon content of the iron, and to give a lower nitrogen content in the finished steel. While this process is economical in fuel, and therefore suited to Swedish conditions, it would appear that the use of the Bessemer plant has regained favour because of the scrap position. Scarce supply of first grade scrap, leading to increased price, has brought the converter into its own. This permits of flexibility, for it is not uncommon to find Bessemer converters, and open hearth, arc and induction furnaces in the same melting shop, so that in times of plentiful supply of scrap, the balance of favour turns to the electric and open hearth furnaces.

At Fagersta, for example, there are two 20 ton converters, one 80 ton open hearth furnace, three 10 ton induction furnaces, and one 25 ton arc furnace. Again, at Surahammar there is one 35 ton acid open hearth furnace, one 28 ton basic open hearth furnace, three arc furnaces of 5, 20 and 25 tons capacity, and two high frequency induction furnaces of 10 cwt. and 8 tons capacity. Firing of the open hearth furnaces is mainly by oil, a light oil being used to maintain a low sulphur content in the steel: after the melt out, a heavier oil may be used. A feature of the larger type arc furnace practice is the use of an induction stirrer: oxygen lancing is also widely practised in order to control the silicon content. There is little doubt that, because of the superior raw materials, the Swedish industry does not meet the difficulties experienced in British plants, particularly with sulphur and phosphorus.

Use of Sponge Iron

While progress has been made in the output of high quality steels, this branch of the industry has in the past been hampered by the rising costs of charcoal iron. This difficulty has been overcome by the introduction of sponge iron and coke pig iron. In the sponge iron process there is not the same opportunity for the removal of impurities as there is in pig iron manufacture, and the purest of ore is therefore required for its starting point. Sponge iron of 94% iron content can be made, and an excellent starting material is available in the high quality slicks, which contain about 70% iron. This material, after magnetic concentration, consists of almost pure mineral ore. The sponge iron process provides an economical addition to Sweden's iron making capacity, in that the amount of fuel required for the extraction of iron from its ore is reduced by it. The process has been a great help to the producers of high quality steels, and in the none too distant future this process may be turned to good account in the production of ordinary steel.

Coupled with this more recent development of sponge iron, normal coke pig iron produced in small units and using high quality ore has also become a basic raw material for high quality steel production. These processes, along with the use of hydro-electric power and of new alloys, have resulted in the once famous charcoal iron being no longer important.

During the last few years, increased emphasis has been placed on electro-metallurgical processes. An example of the use of electric furnace steel making can be seen at Fagersta, where the large arc furnace unit (25 tons capacity and with basic lining) may in many ways be regarded as the pivot of operations, since it can be worked in duplex, receiving hot metal either from blast furnaces or from the Bessemer plant, or it can take metal scrap and pig separately, or in varied amounts of each, and refine the charge to an adjusted composition. The yearly output from this furnace is 40,000 tons.

Casting pit practice varies from one plant to another. Thus, at Smedjerbacken, the normal way of casting is by bottom pouring: the moulds are tar dressed with their wide ends up. At Surahammar, where the steels produced are fully killed, deoxidation being brought about by the addition of silico-manganese in the furnace and of aluminium in the ladles and moulds, most of the ingots are top poured. The ingot moulds are provided with hot tops in the form of slabs placed into the tops of the moulds. These slabs are made from Dolomite, charcoal and coke breeze. Ingot sizes range from 10 cwt. to 35 tons.

The Swedish iron and steel industry is spending considerable time and money on research and it is not uncommon to find the most extensive laboratories in even the smaller works. These laboratories have been most lavishly equipped, as instanced by the installation of a Quantometer at Fagersta.

The British Foundrymen

THE first issue of *The British Foundryman*, the official journal of The Institute of British Foundrymen, made its appearance in January. The new monthly journal will replace both the *Proceedings* and the former *Journal*, issued every two months, but will provide members with considerably more editorial matter. It is hoped that it will be possible to provide space for the publication of more of the work done for the Technical Council, and to publish papers prior to presentation, so as to facilitate discussion at the meetings.

New Division for Birlec

CHANGES have taken place within the Birmingham firm of Birlec, Ltd. A new Heating Division has been formed by the amalgamation of the Furnace and Induction Heating Divisions under the management of MR. J. M. PATON. MR. D. A. HACKETT has been appointed Sales Manager of the new division. A new Engineering Department has also been formed by the amalgamation of divisional drawing offices, under MR. G. H. SHIRLEY as Chief Engineer.

Coil Spring Conference

THE Annual Conference of the Coil Spring Federation Research Organization will be held at the Bedford Hotel, Brighton, Sussex, from Thursday, 23rd, to Sunday, May 26th, 1957. Business meetings will be held on the morning of Friday, 24th, and a Technical Session will be held on the morning of Saturday, May 25th A number of social activities are being arranged during the week-end.

Zinc-Aluminium-Copper Bearing Metal

Properties of Alzen 305 Alloy

THE bulk of technical information concerning bearing materials available in this country to date has concentrated on the traditional alloys—phosphor bronze, leaded bronze and white metal. However, Continental countries were, during World War II, faced with an acute shortage of the primary materials necessary to produce these alloys and, in consequence, German research metallurgists concentrated on the development of a new range of alloys utilising primary materials available on the Continent. As a result of these initial investigations, alloys containing copper and tin were replaced to a certain extent by new ones containing zinc and aluminium as the main constituents. These proved highly successful in many applications, particularly during the war, but on the cessation of hostilities Germany and her wartime satellites had their engineering interests curtailed to such an extent that their consumption of bearing materials was reduced to a minimum. In addition, copper and tin were again available, and there was a steady reversion to the original bronze bearing materials. This reversion was not entirely due to conservative outlook on the part of the engineering industry, but rather to insufficient time being given for a complete development of the range of new alloys, which resulted in difficulties in manufacture and bearing failures in incorrect applications. Thus, the reversion to the traditional alloys after the war was not surprising.

Post-War Research

During the five years after the war, however, copper and tin prices rose enormously compared with the relative stability of aluminium and zinc prices. This fact resulted in a demand for reopening the original investigations on the wartime alloys. This new development, however, was carried out more thoroughly, with metallurgists working in close co-operation with engineers. After approximately four years of research and large scale application tests, a new zinc-aluminium-copper alloy, Alzen 305*, was announced by Voest—The United Iron and Steel Company of Austria—with practical proof that it could replace the conventional bronzes, and that in some applications it was even superior to them.

The binary zinc-aluminium alloys and also the ternary zinc-aluminium-copper alloys containing up to 3% copper and more than 10% aluminium presented such immense foundry problems, due to their complex solidification properties, that the development had to follow a line eliminating as far as possible these difficulties, and at the same time produce an alloy containing the necessary structural arrangement to give the essential bearing qualities. As a result of this, alloys in the ranges of 30–40% aluminium, 5–10% copper and balance zinc were evolved which obviated most of the foundry problems and exhibited a structure similar in form to the tin bronzes, namely a finely distributed hard ternary eutectic of copper-aluminium-zinc in a relatively soft matrix of zinc-aluminium. Thus the hetergeneous structure requirement of a good bearing alloy was fulfilled.

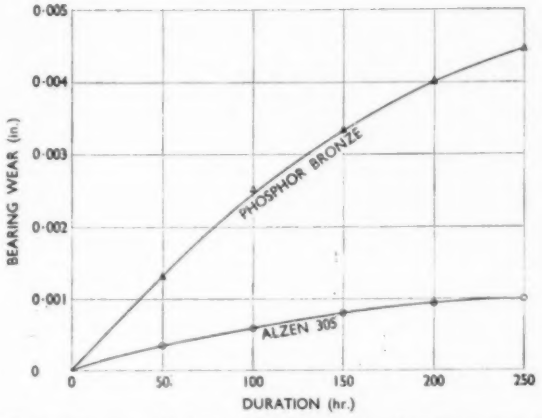


Fig. 1.—Comparative wear tests on phosphor bronze and Alzen 305 bearings. Running speed : 1315-1600 ft./m in.; load : 130-200 lb./sq. in. on projected area ; lubrication : drip feed.

Alzen 305 alloy was originally available as sand cast bearings and chill cast bars, and in fact the majority of the production in Austria is in one or other of these forms, but, in addition, techniques have been established for producing Alzen 305 in the wrought form with highly successful results.

Mechanical and Bearing Properties

The mechanical properties of Alzen 305 compare very favourably with the cast bronzes and gunmetals, (Table I) and, in addition, although the coefficient of expansion is higher than that of bronze, the thermal conductivity is approximately double.

The bearing properties claimed for Alzen 305 have been confirmed in this country by the results obtained from tests conducted by the Research and Development Department of Rubery, Owen & Co., Ltd. These tests were carried out on a machine designed to test two bearings continuously under similar conditions of load and speed. The Alzen 305 and phosphor bronze bearings were 1·56 in. in diameter and 1·25 in. in length and had Brinell hardness of 124 and 113, respectively, compared

TABLE I.—MECHANICAL PROPERTIES OF NON-FERROUS BEARING ALLOYS IN THE CHILL CAST FORM.

Specification	Specific Gravity	Yield Strength* (tons/sq. in.)	Tensile Strength (tons/sq. in.)	Elongation (%)	Brinell Hardness
Alzen 305	4·8	15	20 min.	2 min.	100–150
Gunmetal LG2-C	8·7/8·9	8	12 min.	Nil	55–65
Phosphor Bronze 2B8	8·7	10	16 min.	1·5 min.	60–80
Phosphor Bronze PB2-C	8·7	11	17 min.	3 min.	90 min.
Leaded Phosphor Bronze LPB1-C	8·7	9	14 min.	1·5 min.	65–75

* Approximate values

* The composition of Alzen 305 is covered by British Patent 725,818 completed on March 9th, 1955 and patents are in force in many other countries of the world. Alzen, Ltd., London, are the sole licencees for the alloy in the United Kingdom, the British Commonwealth, United States, Sweden, Spain, Japan, and all other territories not covered by the inventors, whilst C. & L. Hill, Ltd., the Owen Organisation non-ferrous founders, of Willenhall, Staffs, have been granted an exclusive licence to manufacture and sell the alloy in ingot form in the United Kingdom, with a non-exclusive licence for castings and fabricated parts.

with the shaft hardness of 305. The running speed was 1,315–1,600 ft./min. and the load 130–200 lb./sq. in. of projected area. With a bearing clearance of 0·003 in. on diameter, and drip feed lubrication, the maximum recorded temperature of the Alzen bearing was 220° F.

Seizure Effects

The boundary lubrication characteristics are one of the chief attractions of Alzen 305 as a bearing material. In the event of a lubrication failure, complete seizure will not occur until a bearing temperature approaching 400° C. is reached, and even when seizure occurs, the bearing does not weld to the shaft as in the case of bronze. Such a seizure, in fact, results in little or no shaft grooving, and in most cases, it is claimed, does not destroy the bearing itself. It is interesting to consider the progress and effects of seizure on bronze, white metal and Alzen 305 bearings.

Bronze.—After a short duration of dry running, a series of semi-seizures occur, with consequent recovery. This short semi-seizure period is quickly followed by complete seizure, with the consequent fusion of the bronze of the bearing and the steel of the shaft. The shaft usually exhibits severe grooving and the bearing becomes distorted due to metal displacement.

White Metal.—Due to the low melting point of this range of alloys, the period of dry running is only of a very short duration before frictional heat results in softening and eventual melting of the bearing metal. The molten metal coats the shaft and unless the running mechanism is stopped immediately the bearing housing comes into contact with the shaft, resulting in serious scoring. Due to the inherent low strength of white metal bearings, they are usually utilized in a thin shell form with a steel housing support for reasons of rigidity: thus, the time for complete disintegration of the bearing is relatively short, and the consequent damage to the shaft can be great.

Alzen 305.—At the commencement of dry running, the bearing temperature begins to rise and a series of slight semi-seizures result. The bearing, however, recovers quickly from these and returns to more even running. At a temperature approaching 400° C., complete seizure occurs. If any layers of metal are present on the shaft, these are easily removed since no diffusion takes place. The shaft itself will be found in good condition with little or no scoring.

Other Properties

Economically, the use of Alzen 305 offers considerable advantages. The density of the alloy is only 0·173 lb./cu. in., compared with 0·314 lb./cu. in. for phosphor bronze, so that, even at the same price per pound savings of up to 40% can be achieved. There are also savings in transport charges and a reduction in the weight of the finished product.

Bearings may be gravity or pressure die cast in the new material, with a consequent saving in machining time and the achievement of closer dimensional tolerances. Furthermore, Alzen 305 can be continuously cast by techniques similar to those widely used for the continuous casting of aluminium alloys. Physical properties obtained on continuously cast Alzen bars have been exceptional, tensile strengths of 36 tons/sq. in. and elongations up to 8% having been attained.

The corrosion resistance properties of Alzen 305 lie mid-way between those of the bronzes and the zinc-base die casting alloys, and its use in not, therefore, recommended where sea water corrosive conditions prevail. Nevertheless, in the case of centrifugal pumps with pure water lubrication, Alzen bearings have proved satisfactory.

Nuclear Graphite Ltd

THE A.E.I.—John Thompson Nuclear Energy Co., Ltd., and The Morgan Crucible Co., Ltd., are forming a joint company, Nuclear Graphite, Ltd. This company will specialise in the machining of graphite blocks for the construction of the massive graphite moderator piles in atomic reactors—similar reactors to those in use at Calder Hall. To this venture, The Morgan Crucible Co., Ltd., brings its unique experience in handling graphite, having been engaged in the fabrication of this and kindred materials since its formation in 1856. The Company holds a leading position in the development of carbon and graphite materials for industry and has already gained extensive experience in the atomic field. It is of interest to note that it has just completed the manufacture and machining of the special graphite blocks to be employed as the neutron shield for the Dounreay fast breeder atomic reactor. The rapid expansion of nuclear atomic power generation demands a large increase in production capacity and it is now necessary to lay down additional plant. This will provide machining capacity to cover likely expansion in the British nuclear power programme and for overseas orders.

Platinum Metals Review

THE inherent characteristics of platinum—high melting point and exceptional resistance to corrosion combined with excellent working properties—opened up fields for its application from the very beginning of modern industry, and gave it a unique place in the history of research and invention. Interest in platinum's five sister metals—palladium, rhodium, iridium, osmium and ruthenium—was later in development, but over the past thirty years or so they too have found growing applications in chemical and electrical engineering. In order to provide engineers, chemists, metallurgists and other users with a source of current information on the properties and industrial applications of platinum and its associated metals, Johnson Matthey & Co., Ltd., are publishing a quarterly survey of research on these metals and of developments in their application in industry. The first issue of *Platinum Metals Review* appeared in January.

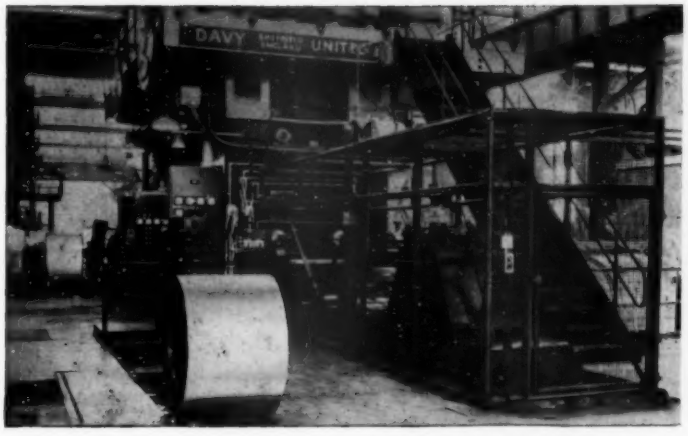
British Meters for Iran

TEHERAN Water Works Authority has ordered Kent water meters for the domestic distribution network throughout the capital. The contract, for 26,000 of the latest ½ in. M2 rotary-piston meters, was negotiated by Kent engineers with the Water Authority and with the Authority's consulting engineers, Sir Alexander Gibb and Partners. It is one of the biggest international contracts of recent years for ½ in. water meters, and was won by Kent against extremely keen competition from Germany, Italy, France and the United States.

Electrical Plant for the Metal Industries

Progress in 1956 Reported

(*Continued from the February issue*).



Courtesy of The General Electric Co. Ltd.

New temper mill at the Velindre Works of the Steel Company of Wales, Ltd.

THE electrical industry continues to play a major part in the provision of equipment for the metal industries. Electrical drives for rolling mills—whether as new construction or for the modernisation of existing mills—undoubtedly constitute one of the outstanding applications of electricity in this field, but a considerable volume of business concerns the smaller motors, switchgear, rectifiers, and, more recently, electronic control equipment. The following information, based on surveys of the activities of a number of the large electrical engineering concerns in 1956, will give some idea of the extent to which metal working depends on electricity. The review is not exhaustive, and is confined mainly to equipment used in the manufacture of semi-finished products.

The General Electric Co., Ltd.

Rolling Mills

As a result of the performance of the temper mills at the Trostre Works of the Steel Company of Wales, contracts were placed for the drives of two further mills for the Velindre Works. These mills, built by Davy and United Engineering Co., Ltd., are now in commission: the drives embody certain refinements based on experience with the Trostre installation. Among overseas contracts, orders have been received for main and auxiliary driving motors, converting plant, power rectifiers and control gear for a 15-stand Morgan continuous merchant mill at the Durgapur steelworks of the Government of India, in addition to large quantities of motors and control gear for other sections of the works.

The use of magnetic amplifiers in the control of steelworks and industrial drives is becoming increasingly popular. Drives for three continuous electrolytic tinning lines at present being supplied to the Steel Company of Wales make extensive use of this type of equipment for the co-ordination of a large number of helper roll drives, and also for build-up and tension control of the reel drives.

In many cases magnetic amplifiers are replacing control exciters, thus using static apparatus in place of rotating machines. However, where a fairly large control power of reversible polarity is required, the magnetic amplifier tends to become rather bulky and inefficient, and control exciters may still be the best solution. Thus, for the auxiliary drives being supplied for the blooming, roughing and beam mills at the Lackenby works of Dorman Long (Steel), Ltd., over 50 Ward Leonard generators are being controlled by a new design of control exciter particularly suited to this type of drive.

A typical example of the growing application of grid-controlled rectifiers to large variable-speed D.C. motor drives is the installation of 12-phase, 2,150 kW., 850 V. equipments for supplying the 1,500 h.p. main stand motors of a 3-stand medium-section mill at the Cleveland Works of Dorman Long (Steel), Ltd. The method of grid control is similar to that used successfully on printing press drives, enabling precise inching and crawling speeds to be obtained. The servo-amplifier is partly magnetic and partly electronic and includes current limit features.

Ore Treatment Plant

Three crushing and washing plants are to be installed in the period 1958–60 for exploiting a manganese ore deposit in South America. The planned output is 30,000 long tons of manganese concentrates a month. A new mill for a mining company in West Africa will incorporate equipment of particular interest, in that Humphreys Spirals will be used to carry out the concentration process. Two 42 in. Symons primary gyratory crushers are in course of manufacture for the Nordberg Manufacturing Co. They are the heaviest crushing machines so far built in this country, each weighing approximately 145 tons. Their height is 14 ft. and overall width 14 ft.

There is growing appreciation of the advantages of iron ore blending plants, and during the year orders have been received for plant of this type for Belgium and India, as well as home orders for a new installation and an extension to an existing one. Export orders include an ore stocking and reclaiming plant for East Africa, comprising a stocking bridge and drag scrapers for reclaiming. Its capacity will be 600 tons/hr. stocking rate and 2,300 tons/hr. reclaiming rate.

Coal Treatment Plant

Cwm Colliery, in South Wales, has recently seen the commissioning of the 200th coal preparation plant for

the N.C.B. This plant is being installed specially for preparing coal for the manufacture of metallurgical coke. Coal from both Coedely and Maritime Collieries in addition to Cwm will be cleaned in the washery, and it is anticipated that the saleable output will eventually rise to around 5,000 tons a day.

Two qualities of coal will be mined, one with a high sulphur content and the other of low sulphur content. For this reason the plant comprises two separate but identical washeries, both contained in the same building and each designed to treat 200 tons/hr. of run-of-mine coal. The Chance sand flotation process has been installed for cleaning all coal down to $\frac{1}{16}$ in. and the Fraser & Chalmers mineral separation froth flotation process for the remaining minus $\frac{1}{16}$ in. fraction.

The washeries operate with a completely closed water circuit with both the concentrates and tailings from the froth flotation section of the plant being dewatered on rotary vacuum filters. A further plant has been included for preparing a picked dirt and washery refuse to enable this material to be re-stowed underground.

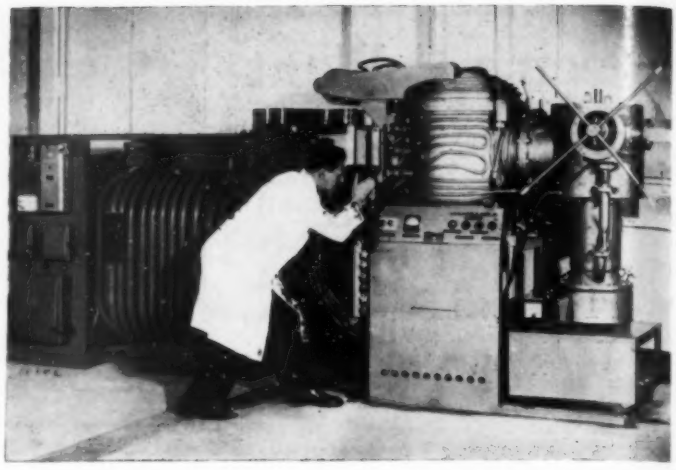
Successful treatment of coal with Bradford breakers continues, and two machines with individual capacities up to 225 tons/hr. are on order for the N.C.B. Opencast Executive. Two spider-mounted Bradford breakers have been ordered for the new Indian Government steelworks at Durgapur in West Bengal. Each will have an output of 350 tons/hr.

Compressor-Blowers

Four turbo-blowers, each of a maximum capacity of 130,000 cu. ft./min. have been ordered for the new Durgapur steelworks project in India. The first two of eight sets comprising a 352,000 h.p. compressor plant for the Ministry of Works are now being erected on the test pits at Erith, and at the Ravenscraig works of Colvilles, Ltd., Motherwell, the power house plant is now being commissioned. A motor-driven compressor of 25,000 cu. ft./min. capacity at 100 lb./sq. in. has been commissioned at the Rustenburg Platinum Mines, South Africa.

Courtesy of The General Electric Co. Ltd.

Heavy duty 42 in. Symons primary gyratory crusher.



Courtesy of The General Electric Co. Ltd.

120 kW. graphite resistor vacuum furnace.

Lifting Magnets

Circular lifting magnets of 56 in. and 65 in. diameter which were built formerly with 4-section coils as standard, can now also be supplied with coils of 6 and 8 sections. By increasing the height of the magnet to accommodate more coil sections, greater lifts can be obtained for a given magnet diameter. For example an 8-section coil magnet of 56 in. diameter will handle approximately the same weight of material as a 65 in. magnet using a 4-section coil; while the lifting capacity of an 8-section coil, 65 in. magnet when handling pig iron exceeds that of its 4-section coil counterpart by nearly 50%. For handling steel plates, bars, sections and tubes, a range of rectangular lifting magnets from 30 in. × 20 in. to 72 in. × 24 in. is now in production. Magnets of this design are particularly suitable for long loads, as two or more can be spaced on a spreader beam to maintain equilibrium and ensure an adequate factor of safety.

Special Furnaces

Vacuum furnaces are being increasingly used in industry. One example, now in production, is a 120 kVA. graphite resistor furnace designed to operate at a maximum temperature of 2,000° C., and a vacuum better than 10^{-5} mm. mercury. It is used for the degassing of metals with affinities for such gases as hydrogen and nitrogen, which affect the properties of the metal adversely, and for brazing, sintering and other treatments. The charge space is approximately 9 in. in diameter × 12 in. deep. This furnace is considerably cheaper than one of similar size employing induction heating.

An example of the extremely high-temperature furnaces required for some of the work on atomic energy

(*Continued on page 139*)

The Long Struggle to Make Malleable Platinum

By M. Schofield, M.A., B.Sc., F.R.I.C.

The present year marks the four hundredth anniversary of the first report to Europe of a "difficult" metal found in South America. In the intervening period, many and varied attempts were made to produce the malleable precious metal we know today as platinum. In this article, the author devotes particular attention to the work of Chabaneau in Spain and Wollaston in this country.

ALL the many applications of platinum today, whether in jewellery, surgical and dental equipment and laboratory ware, or on a larger scale in industry, became possible only when this obdurate or intractable metal was rendered malleable. No other metal has such a history, involving more than a century and a half of hard endeavour by European metallurgists and chemists to harness what was once a curse to Spanish gold-miners, as wolfram was a curse to tin miners, or nickel was Old Nick's Metal to Saxony copper miners. Two anniversaries falling in 1957 bring to mind this long struggle and the share taken by British men of science and by the predecessors of Johnson and Matthey of Hatton Garden ; a struggle in which so many famous chemists of Europe took much interest, and which opened the story of powder metallurgy.

First Reports in Sixteenth Century

Just 400 years ago, came the first report to Europe of a "difficult" metal found in South America, one discarded and dumped into rivers, especially when gold mines became abandoned because of its presence, and when the Spanish government found gilded platinum used as counterfeit. This first reference to it came when Julius Caesar Scaliger, an Italian writer, in referring in 1557 to an early definition of a "metal" as "a substance which can be melted and which hardens on cooling," pointed out two exceptions: mercury was already a liquid ; and also, maintained Scaliger, platinum was one "which no fire nor any Spanish artifice has yet been able to liquefy." Scaliger's reference was an isolated one, remaining in oblivion until platinum history suddenly began to develop in the 1750's. Then followed a century of attention to the metal by many eminent chemists, and by a goldsmith or two adding their practical experience in working precious metals. This century came to a climax in 1857, the year in which a platinum-melting technique provided a second anniversary of much greater significance. For although Robert Hare in 1801, then only a twenty-year old youth but later professor at the University of Pennsylvania, described before the local chemical society his newly-invented oxy-hydrogen blowpipe with which he had melted platinum, this was but a laboratory experiment compared with Deville and Debray's melting of platinum in a small furnace of lime blocks using the oxy-hydrogen flame. Fresh from his brilliant founding of the aluminium industry in France, Deville had turned his attention to melting obdurate metals like chromium, manganese, cobalt and platinum and had patented his platinum-melting process in the name of the Société de l'Aluminium de Nanterre. Debray offered the rights to Johnson and Matthey ; hence the eagerness with which George Matthey foresaw the value and took up the patent rights, this after he had taken to Paris some platinum residues and found the process all that was claimed. Although the Paris firm of Desmoutis, Morin and Chapuis later took up French rights after failing to take much interest, the 1857 melting technique proved a great factor in Johnson and Matthey's vigorous development of platinum, leading to their striking exhibits at the International Exhibition of 1862, when a 3,200 ounce ingot of platinum was on show together with a large platinum still for concentrating vitriol.

Malleable Alloys

Before platinum was at last melted, and before Thomas Cock, Wollaston and others began the first powder metallurgy attack on platinum grains, an alloying element was used, intentionally or otherwise, to render the metal more susceptible to working. The first of these was gold, an alloying metal which was naturally present in that first platinum worked by primitive Indians after fishing out water-worn nuggets and grains of platinum from the river Pinto. In South America the first primitive metallurgy of platinum was carried out after the "free" metal was found, a metal free for anyone's taking, and used for pitch-and-toss or whatever equivalent was played by Indian children with this greyish metal. Bergso has pointed out* that since these Indians could not melt platinum, nor did they use solder of any type, all their fashioning of the metal into crude ornaments and nose-rings was done by welding and cold hammering, using charcoal and the blowpipe, and being dependent on the 30% gold present, which sealed the platinum grains in the working.

In 1735, so long after Scaliger's reference had been lost to Europe, came a second link with South American platinum which proved a real curtain-raiser to the entry of British and other workers on platinum. In that year, a scientific expedition to Peru and Ecuador had as leader Don Antonio de Ulloa, who kept a full record in his "Historical Account of the Voyage to South America." Although war with France caused De Ulloa's ship to surrender to the British and his scientific records to be confiscated, the Admiralty returned his papers since we were "not at war with the sciences or their professors." So his account including observations on platinum as a "peculiar metal" was saved ; and even more important,

* *Nature*, 1936, **137**, 29, and 1937, **139**, 490.

a copy sent to the Royal Society in London. De Ulloa himself went on to other work—to develop the mercury mines of Almaden for example—yet his account roused European chemists to experiment with this " new " metal. One in particular was Sir William Watson, a physician who contributed papers to the Royal Society and brought attention to the work of others. Watson had noted De Ulloa's references to platinum, and moreover had received from Dr. Brownrigg a letter describing how Brownrigg's relative Charles Wood, metallurgist and assayer, had sent him some platinum or Platina de Pinto from Colombia. Brownrigg was an obscure Whitehaven doctor who, as a hobby, had built a laboratory with furnaces, and had in his studies of chemistry examined the crude platinum sent by Wood. Watson persuaded him to report on this strange metal which had a high melting point, and " resisted the power of fire so that it did not respond to the cupellation used for gold and silver."

With specimens of platinum grains from the Choco area of Colombia finding their way to Europe, the period round 1750 became one of intense interest in this South American metal. In Sweden, Scheffer, Bergman and Berzelius studied it, while in France there came papers by Macquer, Baumé, Buffon, De l'Isle and Pelletier. Baumé noted how, like iron, the metal could be self-welded when forged hot. H. T. Scheffer, one-time apprentice to Brandt, gave a full description of " white gold," telling how he had fused the metal by first alloying with arsenic, the latter being subsequently vaporized to remove it. De l'Isle, in 1770–4, used the ammonium platinichloride method of preparing finely divided platinum, and then agglomerated the particles. De Morveau tried alloying with lead, while Achard, famed for sponsoring the beet-sugar industry, is believed to have made the first platinum crucible by use of arsenic. The Abbé Rochon purified platinum grains " in a strong fire " with nitre and sulphate of soda, adding a small amount of tin-copper alloy before fusing in " a violent heat." By 1772, Baron von Sickingen made a full investigation into the platinum problem, making it malleable by alloying with gold or silver, and almost anticipating Wollaston's technique when he dissolved platinum alloys in aqua regia, precipitated ammonium platinichloride, heated this to yield metal grains, and hammered the fine platinum to effect cohesion.

The Work of Chabaneau

Towards the end of the eighteenth century came the first of the two dominant phases or periods in the history of malleable platinum. It was a French academic man who became the first father of platinum-working on an appreciable scale—this before Wollaston came on the scene. Pierre Francois Chabaneau left his native France for Spain when enticed there to teach at the famous Vergara academy. From there he moved to Madrid, where Charles III of Spain built for him the finest chemical laboratory of the day. He had as colleague his countryman Proust, the same " Don Luis " Proust who in 1799 was granted for his Madrid laboratory no less than 46 kilograms of crude platinum and 18½ kilograms of " purified " platinum—that is, more platinum than was to be found in the rest of the world's laboratories put together. Although platinum had been a bugbear to Spain, and although, since it had been used to adulterate gold from the Choco district, it had been accumulated under the care of royal guards, and large quantities taken and thrown into the Bogota River, the Spanish King, nevertheless, saw that Proust and Chabaneau would make something of it. This sponsoring of platinum by Charles III of Spain was a phase in history rather like the championing of Deville's aluminium-making by Napoleon III.

Chabaneau's production of malleable platinum was attained partly by guesswork in fulfilling two essentials for success. First, the metal must be separated from those other members of the platinum group—rhodium, palladium, osmium, iridium and ruthenium—which occur in native platinum. Secondly, the pure platinum sponge must be compressed to a malleable ingot while still at a high temperature. Chabaneau was to some extent fortunate in hitting upon a technique in days when the other platinum metals had still to be discovered, yet he deserves full credit for persistence when variable amounts of such unknown metals gave varying properties to his platinum. " Away with it all. I'll smash the whole business. You'll never again get me to touch the damned metal ! " was his cry on one occasion when his patron, the Marquess of Aranda, arrived at the laboratory to see Chabaneau hurling out of the window his platinum residues. But he was persuaded to return to it, and succeeded under the eye of the Spanish King, who spent long hours in the laboratory watching the new metal take shape. Chabaneau had as collaborator during his early struggles Don Fausto de Elhuyar, one of the two brothers eminent in tungsten history. He was later granted a life pension and letters patent establishing priority for his platinum processing. As a measure of the success attained in this " platinum age " in Spain, some of the results may be summarised. There was Chabaneau's 23 kilogram cube of platinum which the Marquess of Aranda tried to pick up : " You are joking ; you have fastened it down to the bench ! " This 10-centimetre cube or ingot was to remain the largest until outbid by Johnson and Matthey's ingot of 1857—one produced by the easier technique of melting, it should be noted. But most impressive was the manner in which Chabaneau's platinum in the hands of the Paris goldsmith Jeanety was fashioned into crucibles and laboratory ware for the scientists of Europe, into a coffee-pot shown by Lavoisier to the Academy, and into snuff-boxes and watch-chains. Sir Joseph Banks obtained his crucibles from Jeanety, for example, that is from Jeanety's working of Chabaneau's platinum as distinct from Jeanety's earlier platinum worked by the Scheffer arsenic-alloying method.

Wollaston's Contribution

In coming to the second " platinum age," centred in London, the beginning may be traced to the publication in 1800 of Richard Knight's " New and Expeditious Process for Rendering Platinum Malleable." Knight, the son of an ironmonger, compressed his ammonium platinichloride into a conical crucible with cover, reduced it to platinum at a white heat, and hammered in a red-hot stopper to yield a platinum button which was hammered and further heated. Next Thomas Cock, assistant to William Allen at the Plough Court Laboratory, introduced a modification in which a strong iron mould was used for compressing the spongy platinum until no air was left within, the metal being then intensely heated and hammered. But pride of place in this British platinum school goes to William Hyde Wollaston, with a platinum process which earns for him the title of " father

of powder metallurgy." There is a hint in Knight's 1857 Encyclopaedia that Wollaston took some ideas from Cock after visiting his laboratory; yet little it could have been, for Wollaston was the true scientist in his work. He had as collaborator in studying platinum, Smithson Tennant, and four sister metals, palladium, osmium, iridium and rhodium, came from their labours as an auspicious start. Wollaston worked his process as secret, made a fortune of £30,000 from platinum fabrication, and then, strangely enough, published just before his death the whole process in a Bakerian Lecture for all to see. Wollaston's success came from washing fine platinum powder in a wooden mortar, making a mud of s.g. 4·3 with water, compressing to a cake of s.g. 17 to 17·7 in a conical brass barrel-mould, and using a lever press in place of Cock's screw press. He used a charcoal fire to remove moisture and grease, and then a wind furnace fired with coke to effect cohesion before hammering, reheating and forging. With his avoiding iridium dissolving by diluting his aqua regia used for crude platinum, with his warnings against work-hardening the metal powder, Wollaston in his Bakerian lecture had reached his swan song, and had scored a triumph for the British platinum industry. Chemists like Berzelius would apply to London for platinum apparatus rather than to Jeanety's successors in Paris.

A most striking use of platinum on a large scale came when Richard Farmer, sulphuric acid maker on Kennington Common, got Wollaston to supervise the construction from his own platinum of a 323-ounce concentrating vessel costing £300. A chemical manufacturer named Sandemann had one made weighing 423 ounces, while a third vessel of 828 ounces came in 1820. Wollaston passed on, but P. N. Johnson, founder of a famous firm, took up the story, for Johnson had worked with his brother-in-law Cock. Following a fruitful collaboration between Matthey and Sellon on the one hand and with Deville and Debray on the other, Britain became leader in the field, with patent soldering by oxy-hydrogen replacing the old gold-soldered joints used in producing more than 160 acid-concentrating vessels.

Aluminium-Clad All-Weather Hangars

THE problem of securely housing aircraft in varying climatic conditions, and at the same time keeping them ready for take-off in a matter of seconds, is currently being solved by the provision of hangars of a new type. Built by The Coseley Engineering Co., Ltd., of Lanesfield, Wolverhampton, the hangars are designed to overcome one of the biggest climatic problems—winds that can blow for days at speeds up to a hundred miles per hour. One of their most interesting features is the construction of their doors; these are of the roller-shutter type, able to withstand a wind loading of 20 lb./sq. ft., and yet can be fully opened in 30 seconds. The hangars are steel-framed, and clad with unpainted Noral "Industrial" corrugated aluminium sheets, curved at the eaves for appearance, and also to allow snow to slide off where applicable, and strong enough to take a snow load of 60 lb./sq. ft. Each of the two bays of each hangar is 100 ft. long, 83 ft. wide and 34 ft. 6 in. high; the doors, which are in three 25-ft. sections, are situated across the 83-ft. ends.

The doors are constructed of aluminium panels operating with counter-weights on the release of a locking device, and a clear opening is attained in the short time mentioned. Alternatively, the doors can be operated electrically, while manual gear is used for the less important operation of closing them. The aluminium for these doors is Noral B51SWP alloy (to B.S.S. 1476—HE30WP) for the frame sections, with "Industrial" aluminium trough section faced with flat sheet of Noral 3SH alloy (to B.S.S. 1470—NS3). The durability of the alloy used is such that painting is considered unnecessary.

In doors of this kind, which must continue to function efficiently in probable cases of high winds, stiffness is of the utmost importance, on the one hand to eliminate rattling and on the other to avoid the possibility of jamming owing to excessive deflection. This has been achieved very successfully by a unique design of panel construction which exploits to the full the high strength/weight ratio of the aluminium alloy sections and cladding media, giving an extremely stiff yet essentially light door.

Palmers Hebburn Works Contract

THE Constructional Steel Division of the Palmers Hebburn Works of Vickers-Armstrongs (Shipbuilders), Ltd., has been notified of an order of considerable interest. They are to receive contracts for the whole of the constructional steelwork for the nuclear power station at Berkeley, on the estuary of the River Severn, in Gloucestershire. The power station is being built by the A.E.I.—John Thompson Nuclear Energy Co., Ltd., and the consulting engineers are W. S. Atkins and Partners. Constructional steelwork has been produced at the Palmers Hebburn Works since 1935, and the works have played a considerable part in the post-war extensions which have taken place throughout Britain.

Electrical Plant for the Metal Industries

(*Continued from page 136*)

and guided missiles is afforded by an unique resistance furnace, capable of reaching a temperature of 3,000° C., which has been installed at the Atomic Energy Research Establishment, Harwell. Designed in association with the Establishment, it has a useful working volume of 3·25 cu. ft. and can take a charge weighing 240 lb. The furnace has been built to assist experimental studies of the making of graphite, a material which will be used extensively as a moderator in nuclear power stations.

Photo-electric Flame and Smoke Control

Extensive use is being made of photo-electric equipment for detecting and recording smoke in chimney stacks. The equipment, complying with B.S. 2740, is constructed to permit a continuous small flow of clean air across the projector and receiver glasses, which are mounted in slides to simplify cleaning. A flame monitor has been developed for cutting off the fuel supply promptly in the event of flame failure in oil-fired plant. An antimony photocell is used so that false indication from the luminance of the firebox cannot occur, the cell being insensitive to infra-red light.

(*to be continued*)

The Extraction of Tungsten from High Speed Steel Grinding Swarf and Scale

By F. H. Scott, Ph.D., B.Met.

A process is described for the recovery of tungsten from grinding swarf or scale. The process has been found to give satisfactory results and is claimed to be an economic proposition on a pilot plant scale for sufficient by finely divided material.

DURING the manufacture of steel components and tools, there is a certain amount of wastage of material. Hot working and heat treatment operations may result in oxidation of the surface layers and the production of scale. In subsequent machining operations some of the material is converted into turnings, and a small proportion into grinding swarf. Turnings are usually returned to the steelworks, via the scrap merchant, for remelting, segregation of the various materials being adopted where highly alloyed steels are in use. Scale, too, may be charged in the open hearth steelmaking furnace to assist the refining operation, but the handling of grinding swarf in this way is not normally an economic proposition. This may no longer be true if the steel is highly alloyed. In the following pages details will be given of a suggested method of extracting tungsten from high speed steel grinding swarf and scale.

Although grinding swarf comprises a mixture of metal, oxide and abrasive, its alloy content may be of the order, of 75% of that of the metal. In high speed steels, the tungsten figure may range from 3 to 15%, and owing to its high cost the possibility of recovering it is worthy of investigation. There are a number of ways in which the problem can be attacked. The swarf may be cleaned, possibly by magnetic separation, and the metal-containing fraction remelted with a solid base. Recovery by such a method is not complete and difficulty may be experienced due to the fluxing action of the abrasive material.* Furthermore, the final tungsten content may be lower, depending on the base material with which it is melted.

A second method makes use of the alumino-thermite reaction of the oxides of the swarf or scale with finely divided aluminium. The reaction is violent and extremely rapid, and the resulting product—perhaps half the weight of the original charge—may have a tungsten content about double that of the charge. The chief disadvantage of the method is that it is difficult to control the aluminium content of the final product.

A further unsatisfactory feature of the foregoing techniques is that the production and collection of swarf and scale inevitably results in contamination with steels other than tungsten high speed steels, and these contain elements which are retained in the resulting product. It seems desirable, therefore, to use a method involving extraction of the tungsten rather than merely to process the waste material. The method to be described—a modification of the Oxland process used in the extraction of tungsten from its ores—was found to be an economic proposition at the pilot plant stage: the cost of processing a charge of such waste material being about the same as the marketable value of the swarf or scale.

TABLE I.—RESULTS OF PRELIMINARY SMALL SCALE EXPERIMENTS.

Experiment Number	Charge		Weight of Sodium Carbonate (g.)	Fusion Temperature (° C.)	Tungsten in Charge (%)	Tungsten in Extract (%)	Recovery %
	Material	Weight (g.)					
1	Grindings	50	14	900	4·1	4·6	13·4
2	Scale	50	14	900	4·2	25·7	92·5
3	Scale	100	21	900	6·3	45·1	86·7
4	Grindings	50	14	900	4·1	10·4	30·6

TABLE II.—RESULTS OF EXPERIMENTS USING 20 LB. CHARGES OF SCALE.

Experiment Number	Charge		Weight of Sodium Carbonate (lb.)	Fusion Time (hr.)	Tungsten in Charge (%)	Tungsten in Extract (%)	Recovery %
	Material	Weight (lb.)					
6	Scale	20	7	4	4·7	30·4	97
7	Scale	20	7	4	6·3	44·4	76·5

TABLE III.—RESULTS OF EXPERIMENTS USING GRINDING CHARGES OF VARYING WEIGHT.

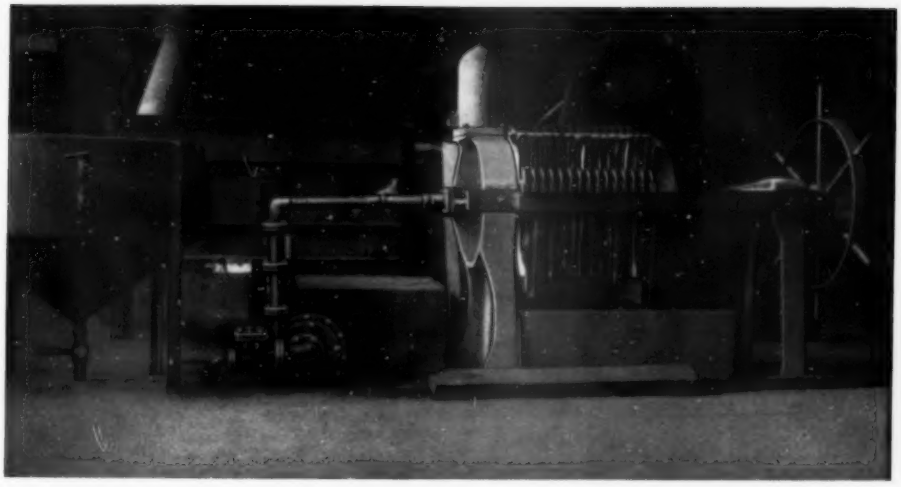
Experiment Number	Charge		Weight of Sodium Carbonate	Fusion Time (hr.)	Tungsten in Charge (%)	Tungsten in Extract (%)	Recovery (%)
	Material	Weight					
9	Grindings	50 g.	7 g.	4	4·1	17·8	79·5
10	Grindings	50 g.	7 g.	1	4·1	18·3	84
12	Grindings	20 lb.	3 lb.	1	4·0	20·8	55·1
13	Grindings	50 g.	12 g.	4	4·1	22·1	80·5
14	Grindings	20 lb.	7 lb.	3 (forced draught)	14·1	56·5	78·5

Preliminary Experiments

The method depends on the oxidation of the grinding swarf or scale and simultaneous fusion with sodium carbonate in the temperature range 800–1,000° C. In the early experiments the tungsten extract was obtained by dissolving in water, decanting from the insoluble material and evaporating to dryness. The results of the first series of experiments, using small quantities of material, are set out in Table I. Somewhat larger scale experiments were then carried out, the tungsten extract still being obtained by decantation and extraction. Treatment of 56 lb. of scale containing 4·7% tungsten with 15 lb. of sodium carbonate resulted in a product analysing 17·8% tungsten, with a yield of almost 100%. Two experiments using 20 lb. of scale were then carried out, with the results shown in Table II. The fused solid was first taken up in 5 litres of water before decanting, when the specific gravity of the solution was 1·2. A series of experiments with grindings was then undertaken, with the results shown in Table III.

These experiments show that oxidation-fusion of tungsten-containing waste materials can be carried out satisfactorily under varied conditions. A good recovery of tungsten was attainable, but the tungsten content of

* J. F. Nye, unpublished communication.



General view of the pilot scale plant.

the product was not as high as could be desired. Moreover, the product was a deliquescent solid which was not easy to handle, and a more satisfactory method of obtaining the final concentrate was desirable.

Calcium tungstate is precipitated from neutral tungstate solutions by the addition of calcium chloride. Under these conditions the calcium tungstate is formed as a coarse precipitate, which settles rapidly to the bottom of the container. This method was investigated and found to be suitable for the processing of grindings and scale, giving a higher assay of tungsten in the product, and eliminating the possibility of contamination with molybdenum, the only element likely so to interfere.

The fused grindings are most easily dissolved in hot water, and this was effected by treating the hot fused material with cold water. After decanting the tungstate solution, commercial hydrochloric acid was added until the liquid was neutral to phenolphthalein. The solution was still in the warm condition best suited for precipitation of the calcium tungstate, which was effected by addition of flaked calcium chloride. The calcium tungstate extract was, in the preliminary experiments, obtained by decanting surplus liquid and taking to dryness. The results obtained are given in Table IV.

Leaching

The extraction of the sodium tungstate from the fused mass calls for some form of leaching, and in the first method tried the material was contained in a bucket skip with a base perforated with small holes, so that it could be immersed in different tanks of water. Experiments were carried out on this basis using three tanks, six separated charges of fused grindings and soda being passed in sequence from tank to tank, being dipped in each tank about 16 times before being discarded. The specific gravity of the contents of the tanks progressively rose, and in the final neutralisation and precipitation it was found necessary to use this as a guide in estimating the quantity of calcium chloride to be added to each tank. The results of these experiments are given in Table V.

The grindings used in these experimental runs analysed 3·9% tungsten, and the recovery achieved was 88%. The method leaves much to be desired, however, and in the pilot plant, although a similar bucket skip was used the water was poured through the mass contained in it. This technique is not now used much in ore extraction metallurgy, but it obviates the need to purchase washing tables and other expensive equipment, and it was satisfactory to the extent indicated in the following trial run using a 12 in. diameter bucket skip. A 28 lb. charge of grindings analysing 14·1% tungsten was fused for three hours with 5 lb. of sodium carbonate, and both the material and the washing water were cold during the leaching. As might be expected, the results in Table VI show that progressively smaller amounts of tungstate are washed out as leaching proceeds. A hyperbolic curve is obtained by plotting the weight of tungsten extracted per litre at any instant against the number of litres of water which have passed through the bucket skip up to that time.

Larger Scale Experiments

Before embarking on the erection of a pilot scale processing plant, a few large scale experiments were conducted. Two runs using ½ cwt. charges of grindings

TABLE IV.—RESULTS OF PRELIMINARY EXPERIMENTS ON EXTRACTION AS CALCIUM TUNGSTATE.

Experiment Number	Charge		Weight of Sodium Carbonate (lb.)	Fusion Time (hr.)	Hydrochloric Acid Added (ml.)	Weight of Calcium Chloride Added (lb.)	Tungsten in Charge (%)	Tungsten in Extract (%)	Recovery (%)
	Material	Weight (lb.)							
16	Grindings	28	7	3½	1,000	7	14·1	38·0	82
17	Grindings	28	7	3	700	5½	14·1	45·2	91·5
18	Grindings	28	5	3	250	3	14·1	53·5	88
20	Grindings	28	2	3	70	1	14·1	51·9	80·5

TABLE V.—RESULTS SHOWING DISTRIBUTION OF TUNGSTEN BETWEEN SUCCESSIVE TANKS IN LEACHING TRAIN.

Tank Number (in order of immersion)	Weight of Calcium Chloride Added (lb.)	Hydrochloric Acid Added (ml.)	Weight of Residue (lb.)	Tungsten in Residue (%)	Weight of Tungsten (lb.)
1	4	650	8·0	43·1	3·45
2	2	400	3·5	45·5	1·58
3	1	150	1·6	44·0	0·70

TABLE VI.—RESULTS SHOWING PROGRESSIVE LEACHING OF FUSED MASS.

	After Passing n Bucket Skips of Water through the Fused Mass, where n equals					
	1	2	2½	3	3½	4
Tungsten Recovery (%) (taking an overall extraction as 80%)	29	67	72	76	79	80

TABLE VII.—ROUGH GUIDE TO AMOUNTS OF SODIUM CARBONATE AND CALCIUM CHLORIDE NEEDED FOR 3¾ CWT. CHARGES OF GRINDINGS CONTAINING VARIOUS PERCENTAGES OF TUNGSTEN.

Tungsten in Charge (%)	Weight of Sodium Carbonate (lb.)	Weight of Calcium Chloride (lb.)
1	3·6	2·25
2	7·5	3·75
3	12·0	8·25
4	18·0	13·5
5	24·0	19·5
6	30·0	24·0
7	37·5	30·0
8	45·0	37·5
9	52·5	43·5
10	63·0	51·0

produced an extract analysing 50% tungsten and showed a recovery of 78%. A 1 cwt. charge of grindings containing 3·9% tungsten was fused for 5¼ hours with 6·5 lb. of sodium carbonate, the soluble matter extracted and the solution neutralised with 150 ml. hydrochloric acid prior to adding 4 lb. calcium chloride. The final extract contained 55·6% tungsten and the recovery was 85·8%. A further 1 cwt. charge consisted of grinding swarf analysing 9·8% tungsten. It was fused for six hours with 13·5 lb. of sodium carbonate, the extract neutralised with 300 ml. hydrochloric acid, and 10 lb. calcium chloride added. The final extract analysed 52·6% tungsten and the recovery was 79·1%.

Pilot Plant

An oil-fired furnace was used for the oxidation-fusion of the grindings or scale. The size of charge which may be processed is dependent on the area of the hearth: as large an area as possible is desirable in order that the simultaneous oxidation and fusion can be effectively carried out. The pilot plant furnace could handle two 1¾ cwt. charges in an eight-hour shift and Table VII gives the appropriate weights of sodium carbonate and calcium chloride required for 3¾ cwt. (two charges) of grindings containing various percentages of tungsten. This is only a rough guide, as each charge of grindings may require adjustment in the light of previous running experience with the batch.

At first the fused grindings were raked out of the exhaust end of the furnace and allowed to cool to black heat on a flat surface. Later, they were simply raked out straight into the bucket skip, where they were allowed to cool somewhat before leaching. Leaching was carried out by spraying, through the skip bucket, water fed by gravity from an overhead tank in which roof water was collected, thus reducing water costs. The bucket skip, complete with fused grindings, was held by crane beneath the spray and above the collecting and precipitating tank.

The latter had a conical bottom and had exit pipes at the sides from which surplus water could be run after precipitation and after the residue had settled. Following this, the slurry could be removed from the tank by means of a large orifice (with a tap) at the bottom of the conical portion of the tank. This orifice was connected by a large pipe, through a pump, to a filter press of the circular plate type.

TABLE VIII.—RESULTS OF A REPRESENTATIVE SERIES OF RUNS IN THE PILOT PLANT.

Reference Number	Weight of Charge (lb.)	Weight of Sodium Carbonate (lb.)	Fusion Time (hr.)	Weight of Calcium Chloride Added (lb.)	Tungsten in Charge (%)	Weight of Extract (lb.)	WO_3 in Extract (%)
M241/3/12	420	25	4½	20	3·1	5½	59·1
M241/3/15	410	25	5½	30	3·1	17	63·9
M255/3/5	420	30	4½	30	3·2	17	60·0
M396/12/2	420	63	5½	63	12·0	52	68·0
M386/12/2	420	70	5½	70	12·6	64	56·4
K4/3/4	420	30	5	30	1·5	18	49·0
K6/3/3	420	30	5	30	4·0	11	54·4
K7/3/3	420	30	5½	30	4·8	13	52·2
K7/3/6	420	25	5½	25	48	11	61·0

Production from the Pilot Plant

The pilot plant was used over a period of time and gave quite satisfactory results fired by medium grade fuel oil. Costs could have been reduced still further by using a lower grade of oil. Commercial sodium carbonate and flaked calcium chloride were used throughout, and neutralisation of the leach solution was effected by the addition of commercial hydrochloric acid.

Results for a representative series of runs are given in Table VIII. The 3¾ cwt. of grindings were thoroughly mixed with the amount of sodium carbonate given in the table, and the mixture divided into two equal charges. The first charge, after fusion, was allowed to cool in the air, and on completion of the fusion of the second charge, the two were mixed together to give a mass at about black heat, which was charged directly into the bucket skip for leaching. The extract precipitated from the neutralised leach solution was allowed to stand for about 1½ hours before decantation was carried out and the slurry pumped through the filter press. Final drying of the concentrate took place in pans on top of the brickwork of the furnace.

In the form of impure calcium tungstate the concentrate is immediately marketable, and can be further processed to the oxide and metal by reprecipitation and hydrogen reduction, if this is desired. Alternatively, it may be used in ferrotungsten in steelmaking, or for enriching remelted base scrap. The concentrate was found to be reduced into the metal in about 20 minutes when added to a charge of molten steel in a basic electric arc furnace.

Of the alloying elements which may be present in the original swarf or scale, nickel, vanadium and cobalt have oxides which are insoluble in sodium carbonate. Molybdenum, which forms a molybdate, is not precipitated as calcium molybdate under the conditions of precipitation used.

Acknowledgments

The author is technically and personally indebted to Mr. S. Graves and the late Mr. Francis Scott for their guidance in the localised aspects of harmoniously organising the human resources at the disposal of people associated with the project.

Wild-Barfield Peddinghaus Agreement

WILD-BARFIELD ELECTRIC FURNACES, LTD., have announced the conclusion of an agreement with Paul Ferd. Peddinghaus of Gevelsberg, Germany, the well-known manufacturers of flame hardening equipment. By the terms of the agreement, Paul Ferd. Peddinghaus are appointed sole agents for the sale and service of Wild-Barfield A.H.F. induction heating equipment in Germany, and Wild-Barfield have the right to use Peddinghaus designs of handling fixtures on induction heating applications where applicable. This arrangement will ensure that German customers for Wild-Barfield A.H.F. equipment will have the advantage of a first-class maintenance and advisory service in Germany, and that customers in England will be in a position to take advantage of any handling devices developed by the Peddinghaus organisation which would not otherwise be available to them in connection with induction heating applications.

NEWS AND ANNOUNCEMENTS

Iron and Steel Engineers Meeting

A MEETING of Junior Engineers, organised by the Iron and Steel Engineers Group of the Iron and Steel Institute, will be held at Chester and Manchester from Monday to Thursday, 11th–14th March, 1957: the object of the meeting is to provide an opportunity for the younger engineers and operators in the iron and steel and associated industries to discuss engineering problems and visit works of interest.

An all-day visit to the Shotton Works of John Summers and Sons, Ltd., on Tuesday, March 12th, will be preceded on the Monday evening by a discussion, introduced by Mr. J. F. R. Jones, on the developments at this works. On Wednesday, the Trafford Park Works of Metropolitan-Vickers Electrical Co., Ltd., will be visited, and on Thursday morning there will be a lecture on "Engineering Problems in Nuclear Power Stations," by Mr. S. A. Ghalib, Chief Engineer, A.E.I.-John Thompson Nuclear Energy Co., Ltd.

Corrosion Testing Summer School

THE Fourth Summer School on Corrosion will be devoted to "Corrosion Testing" and will be held at Battersea Polytechnic from July 15th–19th, 1957. A series of lectures by a panel of speakers, who are authorities on the subject, will be given on the corrosion testing of metals, alloys, metallic and paint coatings, etc. The lectures will be supplemented by a demonstration of corrosion testing apparatus and methods, and by visits to laboratories engaged on corrosion testing. Applications should be made to the Secretary, (Corrosion Testing), Battersea Polytechnic, Battersea Park Road, London, S.W.11.

Aluminium in Electrical Engineering

A SYMPOSIUM on "Aluminium in Electrical Engineering," has been arranged by the Aluminium Development Association for Thursday and Friday, May 16th and 17th, 1957, at the Institution of Electrical Engineers, Savoy Place, London, W.C.2, by courtesy of the Council of the Institution. Twelve papers by electrical engineers with experience in using aluminium will be presented in the course of three sessions under the following general titles: "General and Economic Considerations in Using Aluminium in Electrical Engineering"; "Aluminium in Transmission and Distribution Lines"; and "Aluminium in Electrical Equipment."

The use of aluminium for electrical purposes goes back at least 50 years, but during the past few years considerable progress has been made in further expanding the applications of aluminium in this field. The principal objects of the symposium will be to present authoritative information on experience gained, and to indicate future potentialities for wide and full discussion by electrical engineers, together with the aluminium industry.

Papers will be sent in advance, as preprints, to those registering for attendance. At the symposium, the papers at each session will be introduced by a rapporteur, so that maximum time will be available for discussion and for replies by the authors. The papers and full discussion will subsequently be published as a bound volume. Further announcements about the symposium, including details of papers and timetable, will appear from time to time.

Requests for invitations to attend are open to electrical engineers and others with qualifications and experience in the electrical industry. Applications should be addressed to The Aluminium Development Association, 33, Grosvenor Street, London, W.1.

Nuclear Metallurgy Course

A VACATION DAY COURSE on Nuclear Metallurgy will be held in the Department of Metallurgy, Battersea Polytechnic from Tuesday, April 9th, to Friday, April 12th (inclusive), the hours of attendance being 10 a.m.–5.15 p.m. each day. The subjects and lectures are detailed below:—

Tuesday, April 9th

The Scope of Metallurgy in Reactor Technology, by Prof. J. G. BALL (Imperial College).
Extraction Processes, by W. D. JAMRACK (U.K.A.E.A. (Industrial Group)).
Fabrication Processes, by H. LLOYD (A.E.R.E., Harwell).

Wednesday, April 10th

Physical Metallurgy and Alloying Characteristics of the Trans-Uranic Elements, by Dr. M. B. WALDRON (A.E.R.E., Harwell).
Afternoon: Films and Conversazione.

Thursday, April 11th

Nuclear Constructional Materials and Processes, by L. GRAINGER (U.K.A.E.A. (Industrial Group)).
Irradiation Problems, by J. A. L. ROBERTSON (A.E.R.E., Harwell).
Corrosion—Compatability Problems, by Dr. A. B. MCINTOSH (U.K.A.E.A. (Industrial Group)).

Friday, April 12th

Aqueous Corrosion, by J. N. WANKLYN (A.E.R.E., Harwell).
Fuel Element Technology, by L. M. WYATT (U.K.A.E.A. (Industrial Group)).
Liquid Metals, by Dr. B. R. T. FROST (A.E.R.E., Harwell).

The fee for the course will be £10 10s., except for applicants who normally reside in London, or for those whose local education authority will agree to pay the charges under the recoupment regulations. In these cases the fee will be £1. Application forms should be obtained from the Secretary (Vacation Course), Battersea Polytechnic, Battersea Park Road, London, S.W.11.

Commonwealth Welding Conference

A BRITISH Commonwealth Welding Conference is to be held in London and Saltburn-by-the-Sea from June 17th to 29th, 1957. The objects of the Conference are (*a*) to exchange information on the present technical position of the welding processes and their main applications within the Commonwealth; (*b*) to consider means of improving the flow of technical information about welding among the countries of the Commonwealth; and (*c*) to emphasize the importance of the contribution which welding can increasingly make to the development of modern engineering production. An attractive programme of technical sessions and works visits has been arranged, full particulars of which can be obtained from The Secretary (C.W.C.), The Institute of Welding, 29 Park Crescent, London, W.1.

Metal Physics of Corrosion

THE Metal Physics Committee of The Institute of Metals is organising a Discussion on "The Metal Physics of Corrosion and Oxidation," to be held at Church House, Great Smith Street, London, S.W.1, on the afternoon of Tuesday, April 30th, starting at 2.30 p.m. The discussion will be opened by DR. O. KUBASCHEWSKI (National Physical Laboratory) and DR. C. EDELEANU (Tube Investments Research Laboratories). Visitors will be welcome; tickets for admission are not required.

Standards Conference

THE third annual conference of engineers and others with special responsibilities for standards will take place on Thursday, May 9th. Because of the success of the two previous gatherings of this kind (which were held at British Standards House) this year's meeting will be at Church House, Westminster, enabling many more people to attend.

The conference is being arranged jointly by the British Standards Institution and the Institution of Production Engineers. Mr. H. Stafford, Chairman of the I.P.E.'s Standards Committee, will preside. It will provide an opportunity for discussion of the practical application of standards on the factory floor. The agenda will include items on the role of national and company standards; the development of a coding system for British Standards; and international standards work.

Application forms for tickets may be obtained from B.S.I., 2, Park Street, London, W.1. A registration fee of £1 1s. 0d. (including the cost of a buffet luncheon) will be charged.

Operational Research in Industry Lecture

THE 1956 George Bray Memorial Lecture of the Institution of Production Engineers is entitled "The Scope for Operational Research in Industry," and will be given by MR. STAFFORD BEER, Head of the United Steel Companies' Department of Operational Research and Cybernetics, in the Sheffield City Memorial Hall on Monday, March 18th, 1957 at 6–30 p.m. The chair will be taken by MR. E. W. HANCOCK, M.B.E., President of the Institution, and the lecture will be followed by open discussion. The meeting is open to members of the Institution and their friends, and admission will be by ticket only. Tickets may be obtained from the Secretary of the Institution. It is expected that preprints of the lecture will be available.

Electrical Engineers' Exhibition

FOLLOWING recent changes in the Cabinet, Lord Hailsham who succeeds Sir David Eccles as Minister of Education, will now open the Sixth Electrical Engineer's Exhibition at Earls Court on Tuesday, April 9th, 1957. It is particularly appropriate that the Minister of Education should open the Exhibition, since one of its main features will be a 7,000 sq. ft. exhibit devoted entirely to education in Britain's electrical industry.

The Exhibition promises to be the brightest ever staged in this country, by virtue of a 4,750 watt mercury vapour lamp which will be seen in action for the first time at the Exhibition. Made by Hockridge and Hewittic Electrical Co., Ltd., it weighs 60–70 lb. and is 50 in. long and 8 in. diameter. One such lamp would light a 4,200 sq. ft. factory floor, provided the building was at least 45 ft. high, and the Central Electricity Authority have ordered one for one of their most modern power stations.

Courses in Management and Productivity Subjects

THE Industrial Engineering Department of the Loughborough College of Technology has regularly offered three different types of courses in work study each term, namely—(*a*) Management Appreciation (two days' duration), (*b*) Staff Appreciation (one week), and (*c*) the Main Course for the training of practitioners (ten weeks). It is intended to continue to run courses (*a*) and (*b*) unchanged.

The main ten-week course will continue to be available as a coherent whole, but from the beginning of the summer term in May, will be sub-divided into six self-contained courses so that any one may be taken separately if desired. This arrangement is being made to meet specific requests, and hence to give better service to industry. The self-contained courses will be :—

(i)	Work Measurement (time study, synthesis, etc.)	(3 weeks)
(ii)	Work Simplification (method and motion study)	(3 weeks)
(iii)	Production Planning and Control	(1 week)
(iv)	Specialised Applications of Work Study	(1 week)
(v)	Simplification, Standardisation, and Specialisation	(1 week)
(vi)	Communication, Motivation and Men	(1 week)

This arrangement will assist companies to avoid the difficulty they frequently experience in releasing trainees for ten consecutive weeks, by spreading their training over a longer period of time on a "sandwich" basis.

Further information may be obtained from the Head of the Department of Industrial Engineering, Loughborough College of Technology, Loughborough, Leicestershire.

Electricity in the National Economy

A SUBJECT of great importance and interest, "Electricity in the National Economy," has been chosen as the theme of the Ninth British Electrical Power Convention which is to be held this year at Eastbourne from June 17th to 21st. As in previous years, an Electrical Exhibition will be held in conjunction with the Convention. This will be situated in the grounds adjoining the Winter Gardens (where all the Convention's business sessions are to be held) and will occupy over 32,000 sq. ft.

The Convention's seventeen papers can be divided into five groups, covering, respectively, Generation; Transmission and Distribution; Nuclear Energy in Great Britain; Industrial Utilisation of Electricity; and Houses into Homes.

Further details can be obtained from The British Electrical Development Association, 2 Savoy Hill, London, W.C.2.

B.I.S.R.A. "Open Days" at Swansea

THE British Iron and Steel Research Association will hold two Open Days at the Sketty Hall, Swansea,

laboratories, on Thursday and Friday, June 20th and 21st, 1957, for representatives of B.I.S.R.A. member firms and users of steel sheet and strip throughout industry. The Sketty Hall laboratories are devoted to research into problems concerning steel coatings and methods of surface preparation conducted by the Association's Mechanical Working Division. The Open Days will provide the opportunity for showing improvements in existing coating methods which have been achieved, together with developments in the use of new coating materials. Demonstrations will be given on the recently installed experimental line for the production of PVC-bonded steel strip, and on the differential roller tinning pilot plant now being built. Other projects, including the continuous lacquering of steel strip, the use of iron-zinc and iron-tin alloys, and research into methods of gaseous deposition of metallic coatings, will also be displayed and demonstrated.

Personal News

MAJOR-GENERAL R. E. URQUHART, C.B., D.S.O., has been appointed a Director of Duncan Stewart & Co., Ltd., the Glasgow subsidiary of Davy and United Engineering Co., Ltd. He joined Davy-United in an administrative capacity in the autumn of 1955.

MR. F. W. COOPER, Principal of the Chance Technical College, Smethwick, has been appointed Education and Technical Officer to the Institution of Production Engineers. Mr. Cooper will take up his appointment on April 1st, 1957.

MR. D. CAMPBELL, Chairman of Charles Carr, Ltd., and the Non-Ferreous Casting Co. (Birmingham), Ltd., left on February 14th for the West Indies and Central and South America to help foster the Company's business interests in those areas.

MR. W. J. COLE, who has represented the Cambridge Instrument Co., Ltd., in the Liverpool area for the last 27 years has now retired. He is succeeded by MR. K. W. TREVATT who has taken up residence at 2, Hightor Road, Woolton, Liverpool.

MR. J. R. GORDON has been elected Executive Vice-President of The International Nickel Company of Canada, Ltd., and Executive Vice-President of The International Nickel Company, Inc., the Company's United States subsidiary. He joined Inco in 1936 as Director of the Research Department established that year at Copper Cliff, Ontario.

BRITISH OXYGEN GASES, LTD., have appointed MR. F. CLARK, M.B.E., to the post of Manager of the Sales Technical Service Department at Cricklewood. He is succeeded as Superintendent of the General Service Section of the Department by MR. L. B. SMITH. MR. H. J. VINE has been appointed Superintendent of the Photographic Section.

MR. A. W. STONES has been appointed Manager of the Western District of British Oxygen Gases, Ltd., at Birchgrove, Cardiff. He takes the place of MR. J. E. CLARK, who has accepted an appointment with British Oxygen Wimpey, Ltd., which was formed recently for the construction of special rocket projects.

IN connection with the opening of the new combined bar and rod mill at Samuel Fox & Co., Ltd., MR. P. THOMPSON has been appointed Manager of the new Bar and Rod Mill Department, MR. A. E. HANSELMAN, Assistant Manager (Rolling) and MR. L. LONG, Assistant Manager (Warehouse and Treatment). MR. A. CROSSLEY becomes Manager, Steel Treatment Department and MR. C. BROOKS, Assistant Manager of No. 1 Melting Shop.

Obituary

WE regret to record the deaths of the following :—

SIR JOHN CRAIG, C.B.E., until last year Chairman of Colvilles, Ltd., who died at Cambusnethan Priory, Wishaw, on February 1st. He was in his 83rd year, and his service with Colvilles, Ltd., and its predecessor extended over a period of 67 years.

When he became an office boy at the Dalzell Works of David Colville & Sons, at a wage of five shillings a week, the plant consisted of twenty puddling furnaces and two mills, with four 12-ton open-hearth furnaces producing about 500 tons of ingots a week. Today 350-ton tilting open-hearth furnaces are in operation at Clydebridge, a 240-ton fixed furnace is under construction at Ravenscraig, and the annual output of the works in the Colville Group is in the neighbourhood of 2 million tons. For this growth, much of the credit goes to John Craig, who became Chairman in 1916 at the age of 42, and was at the helm during the difficult 1920s, when his conviction that prosperity would return was expressed in the building of the Clydebridge plate mill. In the early 1930s he successfully steered his company through a period of reorganisation, when mergers with other companies led to the formation of Colvilles, Ltd., and after the war he was concerned with Colvilles' part in the steel industry's development plan. Apart from Colvilles, Sir John was active in the affairs of the British Iron and Steel Federation, and of its predecessor, the National Federation of Iron and Steel Manufacturers. He served as president for both the Iron and Steel Institute and the West of Scotland Iron and Steel Institute, the former during the difficult period from 1940 to 1942.

Throughout his life, Sir John was actively engaged in the work of the Y.M.C.A., and he took a great interest in all aspects of industrial welfare. Despite the vastness of the undertaking of which he was the head, he was able during his tours of the plant to address many of the workers by name—a trait which helped to obviate that impersonal atmosphere which is a feature of so many large concerns.

MR. A. J. BEELEY, formerly Production Manager of the Steel Department at Edgar Allen & Co., Ltd., who died recently after a long illness. He joined the Company in February, 1915, and from 1920 until ill-health forced his retirement in 1952, he acted as personal assistant to Mr. C. K. Everitt and, later, to Mr. L. K. Everitt.

AIR-VICE MARSHAL O. G. W. G. LYWOOD, C.B., C.B.E., L.M., who died at his home near Sevenoaks on February 3rd. Air-Vice Marshall Lywood became a Director of Automatic Telephone and Electric Co., Ltd. on his retirement from the R.A.F. in 1946, a position which he resigned on the ground of ill-health in 1955. He remained a valued consultant, and continued as Chairman of A. T. E. (Bridgenorth), Ltd. up to the time of his death.

MR. W. HOLLAND, of James Durrans & Sons, Ltd., who died on Friday, January 25th.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

X-Ray Image Amplifier

INTENSIVE tests with the Marconi Image Amplifier have shown that it can be as valuable a tool of industry as it has proved to be in the field of medicine. The Image Amplifier is a fluoroscopic device containing an electronic optical system, which provides a much more brilliant "picture" than can be obtained by using the normal fluorescent screen. The optical system has been designed so that the final image can be viewed with both eyes in a plane mirror, which may be tilted and rotated to suit operators of any stature, whether seated or standing.

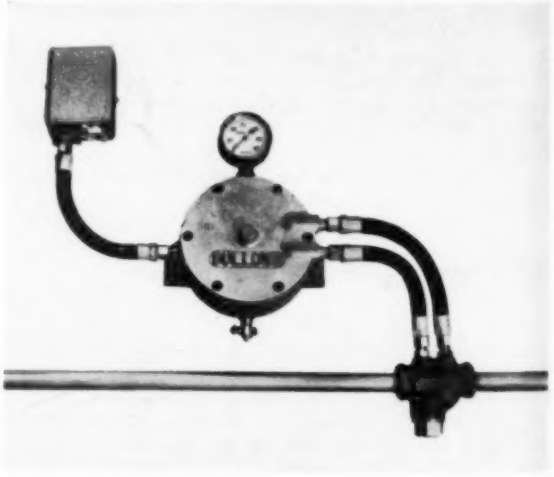
The industrial applications of the Marconi Image Amplifier are fairly self-evident. As in the medical field, greater detail can be seen with less radiation, and the saving in time and expenditure can be considerable. For example, the production of a certain type of investment casting entails the rejection of some 50% after radiographs have been taken. If all the castings are first examined under an Image Amplifier, over 30% can be rejected without the need for radiography, the remaining 70% being radiographed in the normal way. There is thus a 30% saving in the cost of film, in addition to the saving in time. The same principle applies in varying degrees to many industrial components subjected to radiographic inspection. The system overcomes the usual objections to fluoroscopy as a subjective method of testing, since no component is passed into service which has not first been radiographed.

Image Amplifier operation entails the substitution of an electronic image converter tube for the normal fluoroscopic screen. This tube has its own fluorescent surface upon which the X-rays passing through the object will impinge. The fluorescence excites a photo-electric plate and the electrons emitted are accelerated by a high potential applied to the tube by an external power source. A system of electron lenses focuses the image on another screen 1 in. in diameter, where the combined effects of acceleration and concentration give a very considerable increase in brilliance. The optical system then magnifies this image to its natural size for viewing in a convenient mirror.

Marconi Instruments, Ltd., St. Albans, Herts.

Automatic Fan Control Unit

THE air exhausted from the workshop by a spray booth has been heated at considerable expense, and the displacement of air from the shop for exhaust purposes represents a serious heat loss from the factory. Alfred Bullows & Sons, Ltd., announce an Automatic Fan Control Unit, Type V1001/2, which automatically switches off the fan when the spray gun is no longer in use, and switches the fan on again when spraying re-starts. In this way the fan is running only when spraying actually takes place, which may be for only one third of the day, the rest of the operator's time being spent in handling materials and preparation of his work and equipment.



The unit is very simple in construction. A slight local restriction is fitted in the main airline feed to the spray guns on the booth. The airflow caused by the spraying operation induces a slight pressure drop on the downstream side of the restriction, and the variation in pressure on either side of this is used to actuate a diaphragm cylinder, which in turn controls an air feed valve to a small reservoir, and in turn to a pressure switch which completes the circuit for the fan motor.

A permanent bleed to atmosphere is fitted in the reservoir itself, so that when spraying stops, the pressure

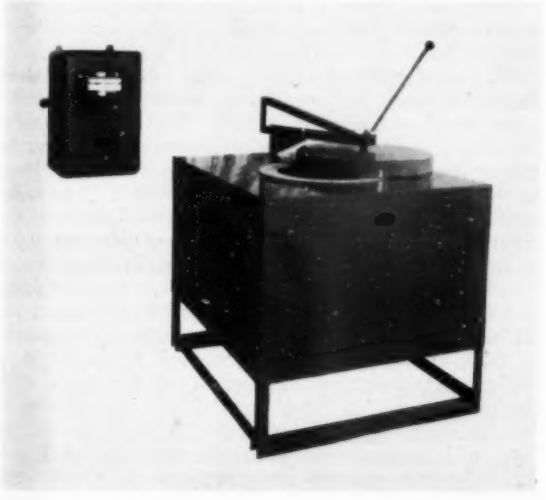
in the reservoir gradually decreases until the pressure switch breaks contact. The rate of bleed is adjustable, and a variable time lag is produced before the fan motor stops. Normal setting is for a delay of 1½ to 2 minutes after spraying ceases, and this prevents the fan cutting in and out repeatedly if the operator triggers at the end of each stroke, or otherwise stops spraying for short periods, such as to change position or to clear a gun stoppage. It also ensures the removal of overspray which may remain in the booth after spraying ceases. When the spray gun is used again the fan starts up automatically within 2 seconds.

Alfred Bullows & Sons, Ltd., Long Street, Walsall, Staffs.

Electric Melting Furnace

HEDIN, Ltd., have recently introduced a new electric aluminium melting furnace for which distinct advantages over older non-electric types are claimed.

The thermostatically controlled electric elements give close control of the heat, and it is possible to keep the temperature of the metal consistently just above



melting point, without wasting heat by going far above it. This also means, of course, that metal losses due to volatilisation are virtually nil. There is no direct contact between the source of heat and the crucible, which means longer crucible life, in addition to which the furnace is very clean to work and requires little or no maintenance. Construction is robust and very simple and the elements, which are arranged for rapid heating, can be replaced quite easily without dismantling the brickwork.

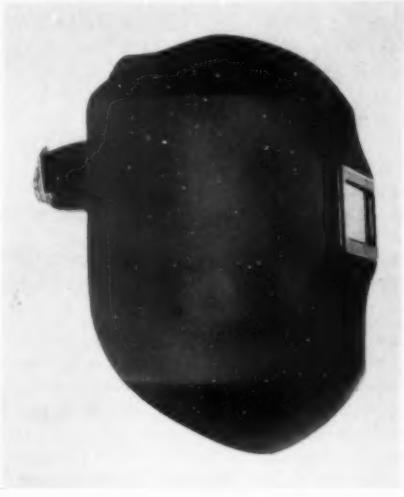
This new furnace is available in two types—bale out and tilting—with capacities of from 50 lb. to 1,000 lb. Special sizes are also built to order.

Hedin, Ltd., Commerce Estate, South Woodford, Essex.

Welding Helmet

A NEW welding helmet, made by Fleming Safety Goggles is of one-piece construction, and has a shape that has been streamlined to improve both comfort and appearance. The deeply curved sides give good protection against sideflash and reflected radiations, and the total weight of the helmet, with filter and cover glass, is only 23 oz.

The glass-holder is of shock-resistant plastic and takes filters size 4¼ × 2 in. The coloured filter is of Protex glass to B.S.679 : 1947, and is protected by a clear cover glass, both glasses being readily changed. The headband is lined with a replaceable sponge sweatband, which is washable. The sponge is soft when it is damp, is non-irritant, and is always comfortable in wear. The size of the headband is controlled by a hexagonal nut, and precise adjustment to give perfect fitting is achieved by fingertip control. The helmet is also fitted with a



chinstrap, which can be adjusted for size, and the helmet remains firmly in position when it is swivelled above the head.

A welding handshield, of similar shape and construction is also available, and both helmet and handshield have been made to comply with all the requirements of B.S.1542 : " Head and Face Protection during Welding."

Safety Goggle Division, J. & K. Fleming, Ltd., 146 Clerkenwell Road, London, E.C.1.

Hexmetal Industrial Linings

IN the fifteenth century, the monks of Beaulieu Abbey made a floor of ceramics fitted into an iron hexagonal honeycomb reinforcement. A British company—Canseway Reinforcement, Ltd.—is now marketing a modern development of this under the name of Hexmetal. When loaded with cement or refractories, Hexmetal provides a lining resistant to temperature variation, abrasion, vibration, corrosion and impact loading. The principle behind this development is the maxim : " pre-cracking prevents subsequent cracking." The metal acts both as a binder and as a separator : it absorbs impact loads and vibrations and inhibits cracking caused by corrosive spillage.

The use of Hexmetal represents a considerable saving of installation costs, as a floor subject to heavy impact load needs to be made of high grade concrete to a depth of 4–6 in., whereas with Hexmetal embedded in the filler a depth of only 1–1¾ in. of high grade material is

required on a foundation of inferior mix. Furthermore, when concrete is being laid on a sloping surface, the honeycomb prevents it from slumping.

Hexmetal is available in steel, aluminised steel, stainless iron and non-ferrous metals, and the cell loading materials used include concrete, granolithic, asphalte and other types of media, depending on the loading and corrosion problems involved.

Causeway Reinforcement, Ltd., 66 Victoria Street, London, S.W.1.

High Vacuum Furnace

THE new Via-Vac F.25H High Vacuum Furnace, has been designed to melt and cast or sinter metals at low pressures, using resistance or high frequency induction heating. Due to the flexibility and adaptability of this new model, the equipment can be used for a large variety of applications in the field of vacuum metallurgy.

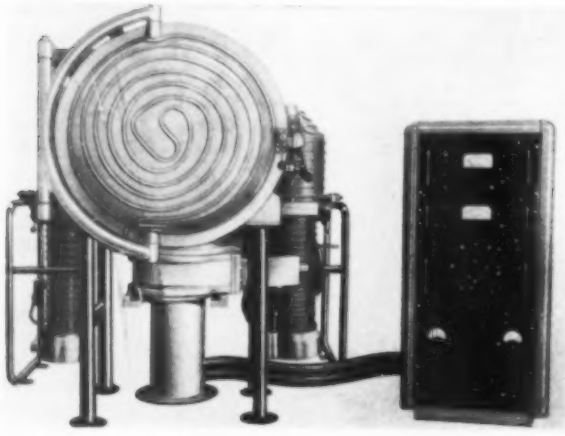
The latest developments in this field have laid emphasis on two main demands :—

(1) Operation, for the purification of metals with the charge hot, at pressures below those of dissociation of the oxides.

(2) Quick access to the mould without the danger of thermal shock to the crucible or the loss of time to permit adequate cooling.

The new range of Via-Vac high vacuum furnaces satisfies these demands, and introduces a large number of new features which add to the efficiency of operation of the plant and the quality of the final product. Provision of an adequate pumping system, which forms the basis of the plant, together with a variety of interchangeable chamber fittings, gives scope for rapid conversion to meet special needs.

The vacuum work chamber is fabricated from mild steel with an internal polished stainless steel cladding, and has a 30 in. internal diameter. The crucible has an internal diameter of 6 in. and height of 12 in. Taking the packing factor as 1·5, a charge of 25 lb. of steel can be accommodated. In order to provide facilities for additions to the melt, a number of charging buckets can be accommodated within the work chamber, and additions may be made at will by the operation of an external selector mechanism. To permit continuous production, facilities are provided for adding charges to the crucible through a vacuum lock. If required, inert gases can be introduced and pressure maintained at a prescribed value by the addition of a needle valve on the work chamber.



All high vacuum valves incorporated in the equipment are power operated and controlled from rotary switches located on a graphic display panel within the main control rack. All controls are mounted on G.P.O. standard pattern panels, accommodated in a 4 ft. totally enclosed control cabinet. Pressure measurements at various points in the system may be taken by means of ionisation and thermocouple gauge heads located at various points. A number of safety devices are incorporated in the design of the plant to ensure conformity with statutory regulations, and to afford protection to both plant and operator.

Vacuum Industrial Applications, Ltd., Wishaw, Lanarkshire.

Direct-to-Line Contactor Starters

A new range of push-button contactor starters has recently been introduced by The General Electric Co., Ltd. Starters now available are suitable for use on three-phase supplies at ratings up to 7½ h.p. at 600 volts, and the range is to be extended shortly to cover ratings up to 30 h.p.

The starters incorporate several interesting features, including a new design of four-pole vertical-lift contactor unit which complies fully with B.S.775 : 1956. This standard stipulates new and more onerous requirements than those hitherto applicable to such equipment, including mechanical duty ; the new G.E.C. contactors are in Class IV, which calls for five-million trouble-free operations. The contactor arc-box is of moulded alkyd—a new insulating material noted for its excellent non-tracking and arc-resisting properties. Another feature is that all the contacts are faced with a minimum silver thickness of $\frac{3}{64}$ in., and that they are easily replaceable.

Overload protection is provided by a triple-pole magnetic trip unit which is adjustable for current rating and for 'Hand' or 'Self' resetting. For isolation, the starter can be supplied with a double-break cam-operated type of interruptor switch capable of safely breaking the stalled-motor current—not merely the full-load current. The contacts of each phase of the switch are in a separate moulded alkyd enclosure, virtually eliminating any possibility of a breakdown between phases. An interlock of conventional design is fitted so that the starter cover cannot be removed unless the isolator is in the 'Off' position. Another safety device is an 'Off' position lock, which enables work on motorised equipment controlled by the starter to be carried out in complete safety.

The whole starter is designed with a view to ease of installation, routine maintenance, and inspection, and is housed in a dust-proof sheet steel case finished in dark grey, with a hinged lid on which are mounted the 'Stop' and 'Start' push-buttons. In addition to the built-in push-buttons, other forms of control can be accommodated such as remote push-buttons or a pilot switch. Provision is also made for mounting an auxiliary switch on the side of the starter with two pairs of contacts, one normally open and the other normally closed, for controlling auxiliary equipment.

The General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2.

CURRENT LITERATURE

Book Notices

THE USE AND WELDING OF ALUMINIUM IN SHIPBUILDING

Proceedings of a Symposium organised by the Institute of Welding, the British Welding Research Association, the Institution of Naval Architects, the British Shipbuilding Research Association and the Aluminium Development Association. viii + 144 pp., illustrated. Published by the Institute of Welding, 29 Park Cresent, London, W.1. Price 32s. 6d. (26s. 6d. to members of the sponsoring organisations), postage 1s. extra.

THE need to review progress in the application of aluminium in the shipbuilding industry, in the light of the development of new alloys and of the new welding processes that have come into use, led the Institute of Welding to take the initiative in convening a Symposium on The Use and Welding of Aluminium in Shipbuilding, which was held in December 1955. This volume contains the 21 papers presented at the Symposium, together with a full account of the discussion and a number of written contributions.

The papers covered most aspects of the welded fabrication and use of light alloys in shipbuilding, and were divided into four groups dealing, respectively, with welding processes and techniques; materials and design; applications (including experience abroad); and applications and economic factors. Three of the papers presented were by experts from France, the Netherlands, and Norway, whilst many participants from overseas contributed to the discussion.

An up-to-date survey of the experience of some of the leading shipbuilding countries in Europe, this volume will be of value to engineers, designers, fabricators, and those concerned with the economics of the use of light alloys in shipbuilding.

SOLDERING ALUMINIUM CABLES

84 pp., numerous illustrations. Obtainable from Aluminium Union, Ltd., The Adelphi, John Adam Street, London, W.C.2., and from Northern Aluminium Co. Ltd., Development Division, Southam Road, Banbury, Oxfordshire. Gratis.

DURING recent years the substantial cost savings associated with the use of aluminium in insulated cables have caused great interest amongst electrical engineers. This interest has been sharpened by the current "credit squeeze." In many cases, however, there has been a pronounced reluctance to use aluminium because of rather exaggerated ideas about the difficulties which might be met in making reliable joints.

The present volume comprises notes on the fundamentals of the problem of soldering aluminium, followed by detailed, illustrated instruction on how to make all the normal types of joint. It covers not only procedures now generally in use in this country, but also methods derived from the rather greater experience available overseas. The instructions cover methods of soldering aluminium conductors and aluminium cable sheaths, and should be of great value to engineers, tradesmen jointers and advanced students. Amongst the appendices are a list of suppliers of all the necessary materials and comprehensive quick-reference current rating tables for aluminium cables. These are, it is believed, the only tables of the kind published so far. They are derived from the C.M.A. tables of current rating factors, which are also included. To many engineers this data will be perhaps the most valuable part of the book.

EXPERIMENTAL STRESS ANALYSIS IN THE U.S.A. AND CANADA

Overseas Technical Report No. 1, published by H.M. Stationery Office for the Department of Scientific and Industrial Research, Price 2s. (36 cents U.S.A.), by post 2s. 6d.

EXPERIMENTAL stress analysis presents the designer with a means of making the best use of the materials from which he has to choose. It is of particular importance in such new fields as those of supersonic flight and the use of nuclear energy. This 22 page report describes current practice and new applications which are being investigated in the U.S.A. and in Canada. It is based on published literature, and on information collected during discussions at various establishments by a member of the staff of the National Physical Laboratory, who was attached to the United Kingdom Scientific Mission in Washington D.C. during 1954 and 1955. Among the subjects dealt with are electrical resistance strain gauges, photoelastic techniques and brittle coatings. Both general and electrical analogy methods are described, and there is a section dealing with high temperature effects in aircraft structures. A bibliography is provided to cover the main divisions of methods of experimental stress analysis.

ALUMINIUM—PRODUCTION OF CASTINGS

Wall Chart No. 4 and Teacher Notes. Fourth of an educational series devised for instruction in schools, technical colleges, and works training establishments, by the Aluminium Development Association, 33, Grosvenor Street, London, W.1. 5s. per set.

THIS Chart is on a subject of particular interest to schools since aluminium, due to its comparatively low melting point, has made possible, with complete safety, practical foundrywork in school workshops.

The Chart itself shows the essential stages in the making of an aluminium casting by the three principal methods of sand casting, gravity-die-casting and pressure-die-casting. It contains brief notes comparing the processes in relation to technique and application; also there is a reference to other, more specialised, methods.

The Teachers' Notes, which are also intended to form a handbook for students' private study where required, open with a brief account of those factors of designing a casting which are important in relation to the requirements of the foundry in order to produce the most efficient result technically and economically. The main processes are then described in turn and, similarly, the more specialised methods are treated in brief note form.

The casting methods are then compared in such a manner as to indicate the best choice for particular types of work, and similar treatment is applied in the section on the choice of alloy. Notes on the operations that follow casting conclude the practical section of the booklet; these are followed by illustrated descriptions of typical applications of aluminium casting to sections

of industry such as building, electrical engineering, transport, etc.

As customary with this series of booklets, there is a page of recapitulation in which the teaching of the book is summarised in eight paragraphs, and following this come headed and numbered paragraphs which tightly link the handbook with the corresponding parts of the Chart itself. An Appendix shows the U.K. production of aluminium alloy castings from 1946 onward, and this is followed by a selected Bibliography.

APPLICATION OF SPRING STRIPS TO INSTRUMENT DESIGN

Notes on Applied Science No. 15. Published by H.M. Stationery Office for the Department of Scientific and Industrial Research, Price 2s. (36 cents U.S.A.), by post 2s. 2½d.

SPRING strips of tempered steel or other elastic materials have many uses in the design of all types of measuring instruments. Their uses include flexible couplings and pivots, the magnification of small movements, and means of producing parallel movement. By using suitable spring strip arrangements in mechanisms; freedom from friction, play and wear of the moving parts is ensured, and no lubrication is required. Instrument design can often be simplified by using spring strips. This publication gives designers a knowledge of the subject which will enable them to make use of spring strips in solving certain problems in instrument design.

Trade Publications

WE have received from Matthews & Yates, Ltd., Cyclone Works, Swinton, leaflet TC/1 dealing with Turbo Cyclone P.V.C. fans which have been designed for laboratory ventilation and other applications where chemical fumes and corrosive gases are liable to be encountered.

FOLIAC products are featured in a new Morgan Crucible leaflet. These are mainly based on graphite, and include lubricating graphite, graphite greases for normal and high temperatures, pipe jointing compounds, and belt dressings.

A NEW Norton Grinding Wheel Company leaflet deals with G-bond vitrified segments with Alundum abrasive for surface grinding steel and cast iron.

THE Holmes-Kemp nitrogen generator featured in Publication No. 65 of W.C. Holmes and Co., Ltd., Huddersfield, produces nitrogen by the accurately controlled combustion of gaseous fuels, followed by elimination of the water vapour and carbon dioxide produced, by cooling and by washing with a solution of monoethanolamine.

DEWRANCE AND CO., LTD., have recently issued Publication No. 687 which gives particulars of hard facing welding rods. There are eight types, some for gas welding and others for metallic arc welding. Particulars are given of the properties of the deposits and their resistance to wear, elevated temperature and corrosion.

THE February issue of *In the Melting Pot*, the Morgan Crucible Company's illustrated folder, is mainly devoted to the new test foundry at Battersea which was featured in the February issue of METALLURGIA. Hints are also given on saving oil by good housekeeping.

A PROGRAMME of courses to be held at The Industrial Safety Training Centre during 1957 has been issued by the Birmingham and District Industrial Safety Group. Specialist groups for whom courses have been arranged include foremen and supervisors, power press tool setters, electricians, maintenance workers, industrial truck drivers, crane drivers and slingers, chemical workers, building contractors, works engineers, and part-time safety officers. Copies of the programme may be obtained from the Manager of the Training Centre at 22, Summer Road, Acocks Green, Birmingham 27.

WE have received from Kodak, Ltd., Kodak House, Kingsway, London, W.C.2, a stock list of Velox, bromide, press bromide, bromide air-mail and Bromesko papers. There is also available a sensitised papers price list dated December 1st, 1955.

THE main feature in the Winter, 1956, issue of *Torch*, the British Oxygen technical quarterly, is the completion of an article on cylinders which deals with the operations at a typical depot, where they are filled, maintained and distributed to customers. Other articles deal with titanium, cast iron welding, accidents due to oxygen enrichment in confined spaces, new equipment, and typical applications of British Oxygen products.

A NEW technical circular (T.C.103) dealing with manipulative equipment for manual and automatic arc welding, has been issued by Quasi-Arc, Ltd., of Bilston, Staffordshire. The circular includes a number of illustrations of some typical uses of manipulative equipment to provide efficient welding. Also included are details concerning roller beds, welding positioners, cantilevers, the radial beam positioner, and the internal welder.

ITEMS of particular interest referred to in *The Nickel Bulletin* for December, 1956, include the nickel plating of molybdenum, beryllium and other "unusual" metals, properties and uses of S.G. iron, and the welding of high-tensile steels. Progress in the production and use of high-temperature materials is reflected in abstracts relating to vacuum melting of such materials, the properties of alloys of the Nimonic series, and the influence of cold working on the high-temperature properties of stainless steels. The literature on corrosion resistance includes items dealing with stress-corrosion in austenitic steels, the resistance of high-alloy steels to corrosion by mine waters, and service experience with iron-containing cupro-nickel alloys. This issue also contains the consolidated "Contents List" for the 1956 volume of the *Bulletin*, together with name indexes and lists of trade names mentioned during the year.

Books Received

"Defects and Failures of Metals: Their Origin and Elimination." By E. P. Polushkin. 399 pp. inc. index and numerous illustrations. Amsterdam/London/New York/Princeton, 1956. Elsevier Publishing Company. Sole Distributors for the U.S.A. and Canada: D. Van Nostrand Company, Inc.; and for the British Commonwealth except Canada: Cleaver-Hume Press, Ltd. 72s.

"Atomic Structure and the Strength of Metals." By N. F. Mott. (The Page-Barbour Lectures for 1956 at the University of Virginia). 64 pp. London and New York, 1956. Pergamon Press, Ltd. 15s. net.

LABORATORY METHODS

MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS

MARCH, 1957. Vol. LV, No. 329

The Removal of Inclusions for Analysis by an Ultrasonic "Jack Hammer"

By George L. Kehl,* Hyman Steinmetz,† and Warren J. McGonnagle‡

Inclusions may be removed from metals and alloys for identification purposes by chemical or mechanical methods. The latter have the advantage that the possibility of chemical change is eliminated, and a new technique is described for the removal of inclusions of minimum diameter of about 10 microns by means of a pointed stylus oscillating at ultrasonic frequencies.

IN the identification of small inclusions in metals and alloys, it is customary to remove the inclusions of interest from an appropriate specimen (usually from a metallographic specimen) and to subject such finely divided sample to appropriate analysis. Techniques of removal consist of either chemical or mechanical methods. In the former, reagents are employed that are selective in their dissolution property, i.e., they will selectively attack the matrix metal and leave the included material as loose debris which may be filtered subsequently from the reagent and gathered for analysis. The principal disadvantages of this method are the uncertainty that the inclusion debris has not suffered some chemical change, and that the residue consists of just the inclusions of interest, and not an agglomerate of different kinds.

Inclusion removal by mechanical methods has been confined largely to probing and loosening inclusions from the matrix metal with a pointed stylus. The operations are generally carried out under a microscope, and the probe manipulated by hand. The method is time consuming and, because of awkwardness of the operations, it is often tedious to secure sufficient sample for analysis.

When inclusions of interest are large and polycrystalline in character, or small and segregated in mass, X-ray diffraction techniques often permit identification without removal. The techniques, however, are sometimes difficult to execute, and the success in identification depends in part upon the size of the collimated X-ray beam, and the precision of incidence on the specimen region of interest.

This paper describes a new mechanical method for removing inclusions of minimum diameter of about 10 microns by means of a pointed stylus oscillating at ultrasonic frequencies. The method works admirably in removing hard and brittle secondary alloy phases, and non-metallic inclusions of either the hard, glassy type or the loose, fluffy kind. Relatively soft and ductile secondary phases are not removed or shattered; rather they are merely cold worked in situ. This circumstance, however, may be of interest in critical recrystallization studies, where it is desired to work harden a selected single grain within a polycrystalline aggregate.

The extraction apparatus to be described consists of the following major components: (1) an ultrasonic driving oscillator designed to match the frequency of a selected barium titanate transducer; (2) a metallic horn attached to the transducer to magnify linear motion; (3) a pointed stylus that makes contact with the inclusion to be removed; (4) a bench-type metallurgical microscope; and (5) two micro-positioners, one to hold the transducer and horn assembly and to permit locating the pointed stylus with precision, and the other to manipulate a quartz fibre to gather up the inclusion debris after extraction.

Ultrasonic Generator

The ultrasonic oscillator, diagrammatically shown in Fig. 1, is designed to match the natural frequency of a selected barium titanate transducer (47 kc./s.). The circuit of the generator is conventional, except for incorporation of a feed-back amplifier system to secure constant amplitude. The unit is capable of delivering energy well in excess of that required for the intended purpose.

Transducer-Horn Assembly

The transducer assembly, illustrated in Fig. 2, consists of the barium titanate transducer and an attached brass horn. The two component parts are cemented together with Tuffbond, or with a similar adhesive. The purpose of the horn[1] is to serve as a transformer and to increase the linear motion of the stylus relative to that of the transducer, by a factor of about 30. In the horn design to be described, the throw of the stylus tip is about 0·001 in. each way from centre.

To secure maximum transfer of energy to the stylus, two factors must be considered in the design of the horn. The diameter of the base should be less than one-half

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† Hyman Steinmetz, formerly Research Associate, Columbia University, is associated with the Nuclear Development Association, White Plains, New York.
‡ Warren J. McGonnagle is associated with the Metallurgy Division, Argonne National Laboratory, Lemont, Illinois.

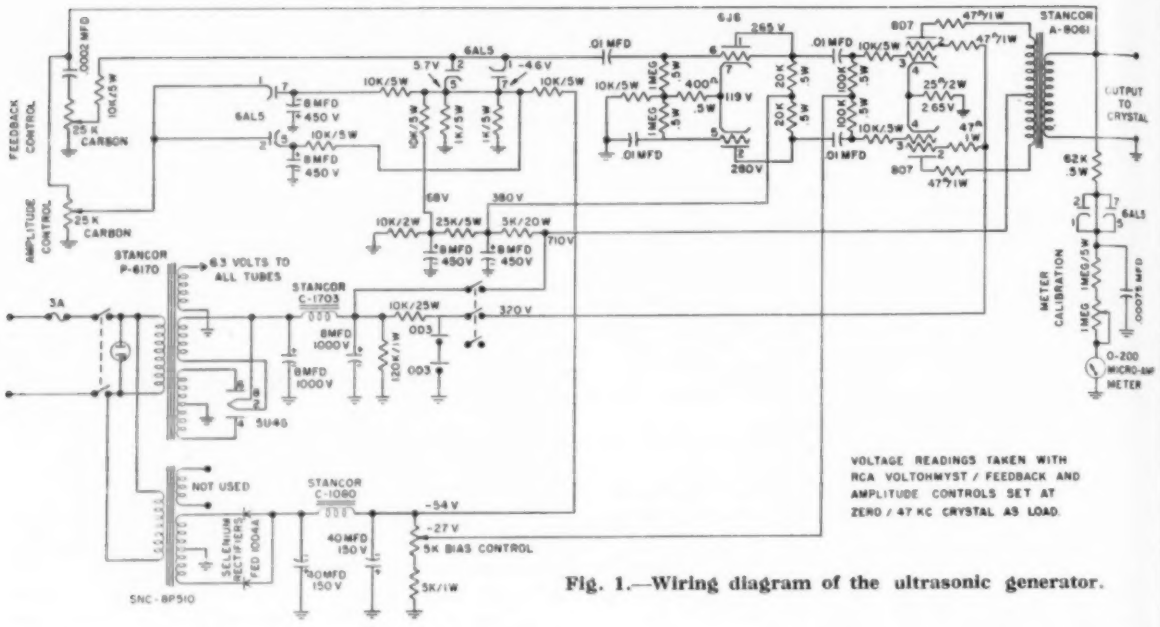

Fig. 1.—Wiring diagram of the ultrasonic generator.

wavelength of the ultrasonic wave passing through the horn material, and the length of the horn from the base to the tip of the stylus should be equivalent to an integral number of half wavelengths. When this latter requirement is fully realized, the cemented interface of the assembly will be at a pressure node with attendant least stress on the joint, and the stylus tip will vibrate with maximum amplitude.

For a transducer of given resonance frequency, the wavelength and physical size of the horn will vary, depending upon the material from which the horn is constructed. From the relationship,

$$V = f\lambda$$

where V = velocity of sound through horn material in in./sec. (for single phase brass, 174,000 in./sec.).

f = frequency of transducer in cycles/sec.

λ = wavelength in in.

the wavelength may be calculated and the maximum diameter of the horn base determined.

The taper of the horn, from the base to the small end,

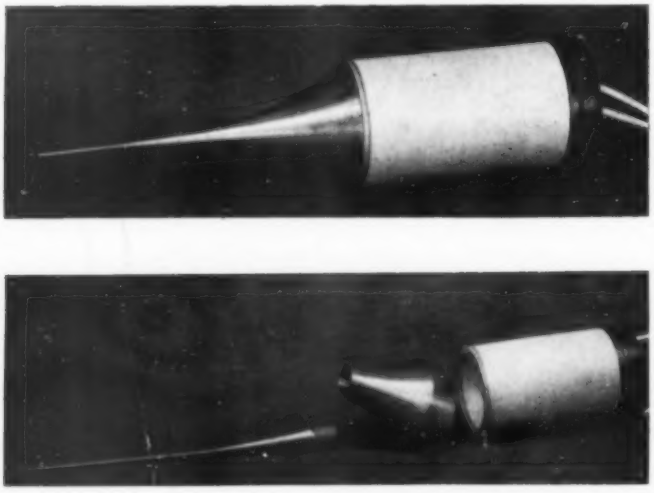

Fig. 2.—The barium titanate transducer and horn assembly, but without stylus attached : (top) component parts assembled ; (bottom) component parts separated.

Fig. 3.—Representative shape of steel stylus point as electrolytically formed. × 67

is best designed exponentially, following the familiar mathematical expression,

$$A = A_1 e^{cx}$$

where A = cross-sectional area at any distance x from the large end

A_1 = area at large end

c = constant

In order to avoid an excessively long horn tip, slight departure from an exponential taper can be tolerated without seriously affecting performance. Machining of the taper is facilitated by matching the contour against a paste-board template.

To facilitate change of the stylus, which is waxed to the small end of the taper in a manner to be described, the lower portion of the horn is detachable from the upper end by screw threads, as illustrated in Fig. 2. This arrangement permits a number of extra horn ends to be fitted with styli, and to serve as ready replacements when points are damaged in use.

Preparation of Styli

At the onset of this development, styli were made from 0·02 in. diameter tungsten wire, electrolytically pointed by a method first described by Pfann.[2] For the application intended, tungsten is not entirely satisfactory owing to its relative softness, short life as a tool, and the loss of tungsten during use which contaminates the inclusion debris.

Currently, styli are made from drill rod, 0·045 in. dia. by about 3 in. long, heat treated to develop maximum hardness by brine quenching from a temperature of 870° C. (1,598° F.). The wire is subsequently pointed electrolytically according to the following procedure:

A solution of 50% glacial acetic acid and 50% nitric acid serves as the electrolyte, and during use it is kept cool, either by an ice bath, or by adding chips of dry ice to the electrolyte at frequent intervals. The heat treated drill rod serves as one electrode and is suspended vertically into the electrolyte from the stage of a micropositioner. A strip of platinum foil serves as the other electrode.

With the electrodes connected across a potential source of 8–12 volts (A.C.), the end of the drill rod is immersed into the electrolyte to a depth of about $\frac{3}{8}$ in., by actuation

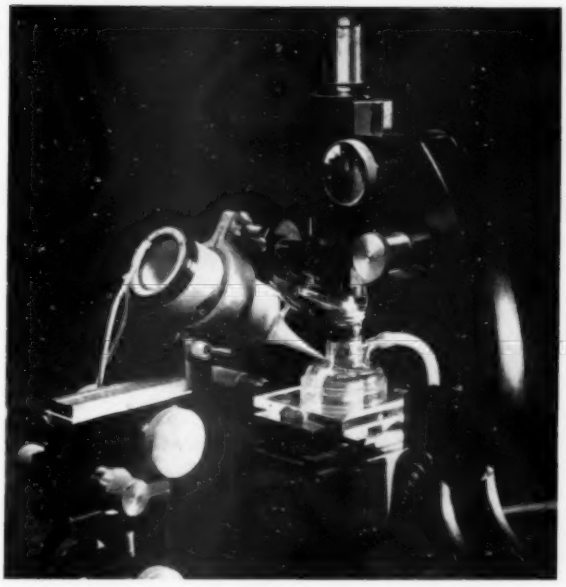

Fig. 4.—Illustrating the microscope arrangement and transducer assembly in operating position.

of the micropositioner, and then withdrawn from the solution. During immersion in the electrolyte, there is an audible hiss attending the electrolytic process. The cycle of immersion and withdrawal should be accomplished in about 2 sec. After about 25 to 30 cycles of operation the end of the drill rod is in the shape of a tapered point, but not of sufficient sharpness for the intended purpose. To achieve final pointing, the drill rod is immersed in the electrolyte and withdrawn at a constant rate until the current is reduced to 0·2 amp. The wire is then allowed to remain in the electrolyte until the current drops to approximately zero, at which time the wire is *immediately* removed from the electrolyte. The approach to zero current is accompanied by a change in tone of the sound referred to above, changing from a hiss to a subdued, intermittent sputter. The last operation of withdrawal

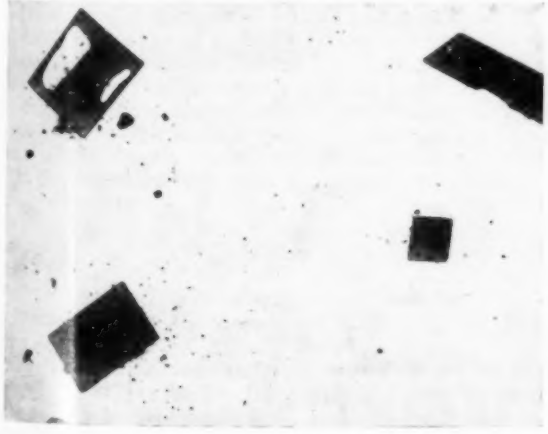

Fig. 5.—Inclusion of UC in a uranium matrix. Note scattered inclusion debris and cavities in inclusions resulting from the vibrating stylus. Unetched. × 150

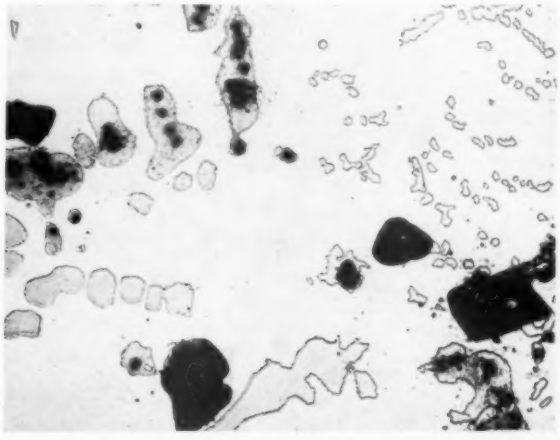

Fig. 6.—A uranium matrix containing inclusions of UO_2 (dark) and U(C,N) (light). Note evidence of precision in positioning stylus on the various inclusions of interest. Unetched. × 150

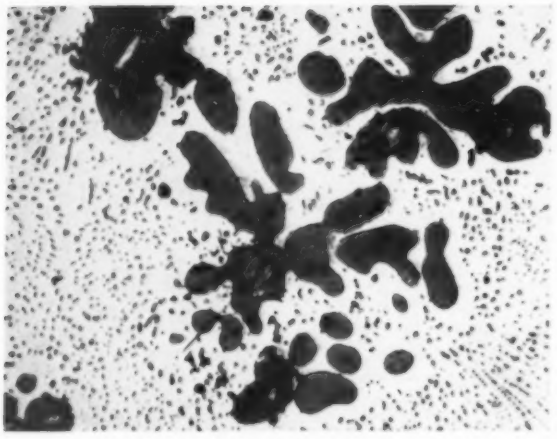

Fig. 7.—Copper oxide phase in a matrix of copper. Note areas in the primary phase where material has been removed. Unetched. × 250

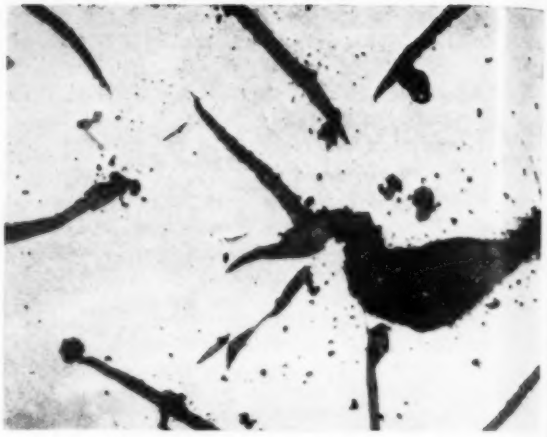

Fig. 8.—Graphite flakes in cast iron partially removed from the matrix. Unetched. × 250

is particularly critical; if not carried out at the appropriate time the final point will lack in perfection. Occasionally, a very fine thread of metal will extend from the point after this last manipulation, but it can readily be removed by very rapid immersion and withdrawal from the electrolyte. This method of pointing takes approximately 5 min., and produces a point that is nearly always perfect, as typically illustrated in Fig. 3.

After pointing, the drill rod is cut into lengths of about 2·5 in. to satisfy the requirement of total horn length, and the stylus subsequently attached to the horn end by inserting it into a drilled hole and affixing it in position with softened hard wax.

Extraction Procedure

The arrangement of the component parts of the apparatus are shown in Fig. 4, with the exception of the micropositioner supporting the pick-up fibre, which is normally placed to the right of the microscope. A specially designed glass hood is placed over the specimen, as illustrated, and purified argon gas passed into the system during the extraction operation. A slit in the hood is provided to allow entry of the stylus into the chamber. This hooding arrangement is necessary if the frictional heat generated at the stylus tip is sufficient to cause air oxidation of the inclusion debris. However, if the debris of interest does not suffer oxidation during extraction, the hood may be removed and the refracting objective replaced by a reflector to provide greater working space above the specimen surface.

The area of interest on the specimen is located microscopically, and while observing the operation the vibrating stylus is lowered until the point makes contact with the inclusion. When this occurs, the inclusion is shattered locally and a shower of debris is formed and scattered in the vicinity of the inclusion. The depth of penetration, and the size of the resulting hole in the inclusion is readily controlled by manipulation of the stylus through actuation of the micropositioner.

When sufficient inclusion debris has been created* to serve as an X-ray diffraction specimen, the fragments are gathered on a glass or quartz fibre suitably coated with grease or an adhesive such as Vistanex. The fibre tip is merely moved over the specimen surface by means of a micropositioner, and contact made with the loose debris.

Figs. 5–8 are illustrative examples of inclusions partially removed by the method described. The inclusion debris is self-evident, and the precision of the extraction method is noted by the position of the resulting cavities within the inclusions.

* In most cases this may be accomplished in 15–20 minutes, excluding the time required to position the specimen.

Acknowledgment

This work was supported at Columbia University by the United States Atomic Energy Commission under Contract No. AT(30–1)1593, and was carried out in co-operation with the Metallurgy Division of the Argonne National Laboratory. The assistance of Messrs. Eric Mendel and Richard Rudolph is gratefully acknowledged.

REFERENCES.

1 Mason, W. P. and Wick, R. F., "A Barium Titanate Transducer Capable o Large Motion at Ultrasonic Frequency," *J. of Acoustical Soc. of Am.*, **23**, 1951.

2 Pfann, W. G., "An Electrolytic Method for Pointing Tungsten Wires," *Trans. A.I.M.E.*, **175**, 1948.

Non-Destructive Testing Conference

THE purpose of the Second International Non-Destructive Testing Conference, which is to be held in Chicago from November 4th to 8th, 1957, is to develop viewpoints regarding the directions along which effort should be expended in the future so that the field of non-destructive testing can most efficiently and effectively advance, advancement being regarded as improved technological and economic service to science and industry.

It is intended that it shall be a "participation conference" rather than an "information conference." The three Conference subjects are: "The Basis for Optimum Test Methods Selection"; "The Relative Advantages and Limitations of Non-Destructive Test Methods"; and "Recommendations for Technical Development and Standardisation"; and it is planned that invited authors will prepare a few (about nine, in all) keynote papers dealing with these subjects. These papers will present individual viewpoints, and they will be discussed at length by the audience "participants" in order to arrive at a majority viewpoint, and possibly one or more minority viewpoints. These viewpoints will subsequently be summarised and published.

A Vacuum Fusion Gas Analysis Apparatus for Use in the Quality Control of Ferrous Materials

By K. Speight, A.Met., A.I.M. and G. M. Gill, A.Met., L.I.M.

Metallurgy (General) Division, British Iron and Steel Research Association

A description is given of a vacuum fusion gas analysis apparatus which has been used for the routine analysis of gases in ferrous metals for more than a year. Designed for use in a control laboratory, the apparatus has a compact, robust, all-metal gas extraction system, and can be resited with the minimum of inconvenience.

IN steelmaking processes, it is necessary to have knowledge of the composition of the bath during the oxidising and refining period, in order that the required specification may be reached in the shortest possible time and with the minimum outlay of reacting materials. To accomplish this, it is usual to have analyses of the melt carried out at intervals throughout the process and, depending upon the end product, analyses for carbon, sulphur, phosphorus, manganese, chromium, nickel and molybdenum may be needed. Three elements which can have a considerable bearing on the physical properties of the finished steel, oxygen, nitrogen and hydrogen, have received little or no attention from the bath sample point of view. If accurate analyses of the gas content of the steel could be accomplished prior to tapping, closer control of deoxidising additions could be achieved, with subsequent savings in cost; the formation of hair-line cracks could possibly be reduced; and there would be a greater possibility of control of nitrogen content. In vacuum melting techniques where reduction of impurities is carried out with gaseous hydrogen, an apparatus capable of analysing the bath of metal for the gas content would be of immense value.

The following is a general description of the vacuum fusion gas analysis apparatus now in operation at the Sheffield laboratories of the British Iron and Steel Research Association.

From comments received from responsible members of the British steel industry, there appeared to be a demand for a strong, relatively mobile vacuum fusion apparatus, capable of withstanding comparatively rough usage and having the capacity to be used in day-to-day routine analysis. The immediate necessity was therefore to replace the rather fragile glass units which were mostly in operation in research and development laboratories with one constructed from a more sturdy material.

Attention was directed to an all metal system and, with the co-operation of Messrs. Edwards (High Vacuum), Ltd., such an apparatus has been developed and successfully operated. The simplicity and size of the equipment, a floor space of 3¼ sq. ft. is occupied, contrasts with other commercial models which occupy a floor area of 18 sq. ft. and which may be liable to more frequent layoffs because of their more delicate construction. (Figs. 1 and 2). A notable feature of the equipment is that vacuum greased joints have been dispensed with completely. These have been replaced with rubber "O"

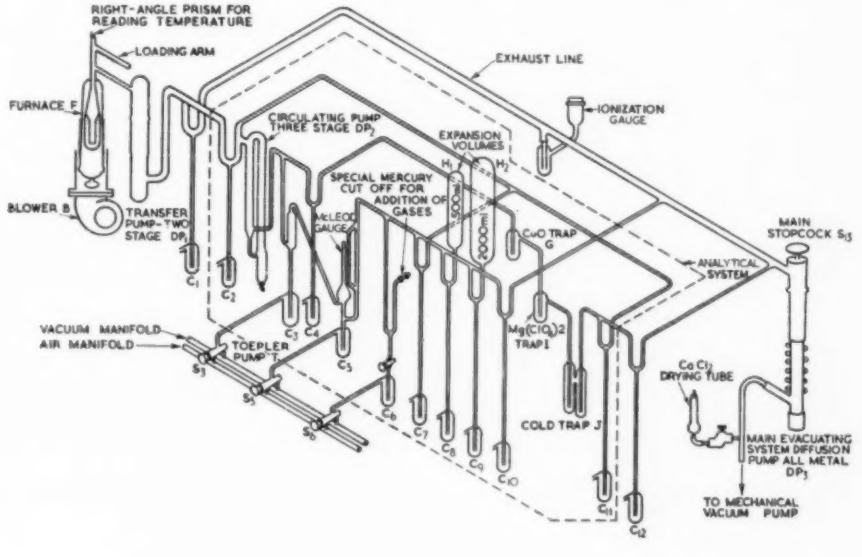

Fig. 1. — Schematic diagram of a typical commercial apparatus

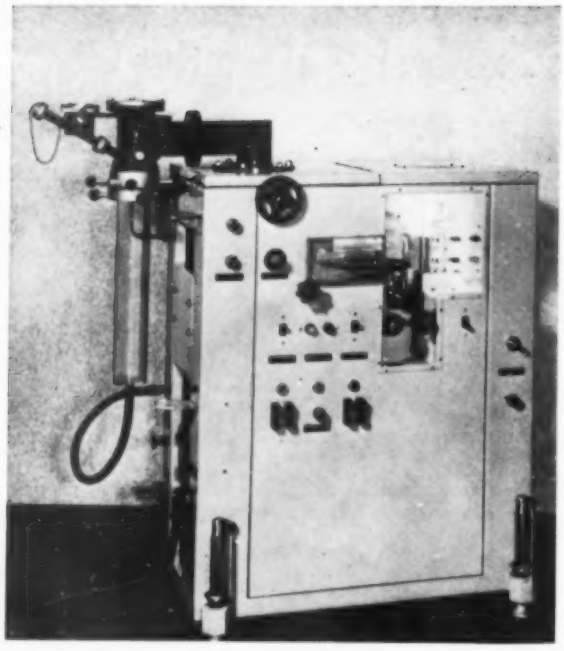

Fig. 2.—Vacuum fusion gas analysis apparatus developed by B.I.S.R.A. and manufactured by Edwards (High Vacuum), Ltd. (H.F. generator not shown.)

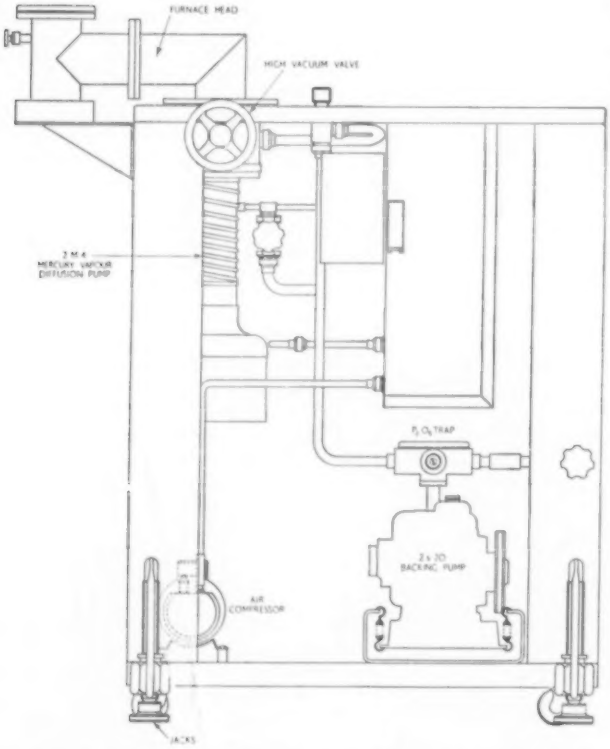

Fig. 3.—Cut-away view of console, showing position of pumps and compressor.

rings, thus meeting a comment by Sloman[1] that waxed and greased joints, particularly, should be kept to a minimum.

The apparatus can be regarded as three separate units: the power supply, the furnace and extraction unit, and the gas collection and analysis units. These will be dealt with in sequence.

Power Supply

The power supply unit was manufactured by Messrs. Philips Electrical, Ltd., and is a high-frequency valve oscillator, Type F.13/1, operating at a frequency of 350 kc./s. The power output is 6 kW. at the generator terminals, and this is fed into a work coil of nine turns of water-cooled copper tubing, the coil measuring $3\frac{1}{8}$ in. inside diameter and having a height of $2\frac{1}{2}$ in. For valve and tank coil cooling, a water supply of 150 gal./hr. at a minimum pressure of 40 lb./sq. in. is required.

The equipment is mounted on skids to facilitate movement, and all the heavier components are removable for the same reason. The equipment as a whole has been so constructed that, should it be necessary to change from high frequency to resistance methods of heating, the minimum of modifications would be required.

Furnace and Extraction Unit

The whole of the remainder of the equipment is housed in a metal console measuring 30 in. in length by 40 in. in height and 16 in. in depth. At each of the four corners of the console, rubber tyred wheels are fitted to aid mobility. When not required, these are raised from the ground by means of four small jacks, which then provide rigidity. (Fig. 3).

The furnace assembly is of the conventional type, consisting of a graphite crucible of 160 g capacity (Fig. 4), centralised at the base of a fused silica tube by means of pure graphite powder passing 200 mesh. During operation, the crucible mouth is closed by means of a mechanically operated stopper. The silica tube has a length of 17 in. and is $2\frac{1}{2}$ in. in diameter. (Fig. 5). Surrounding

1 H. A. Sloman: Eighth Report on the Heterogeneity of Steel Ingots, Spec. Report No. 25, 1939, London, The Iron and Steel Institute.

Fig. 4.—Components of graphite crucible assembly

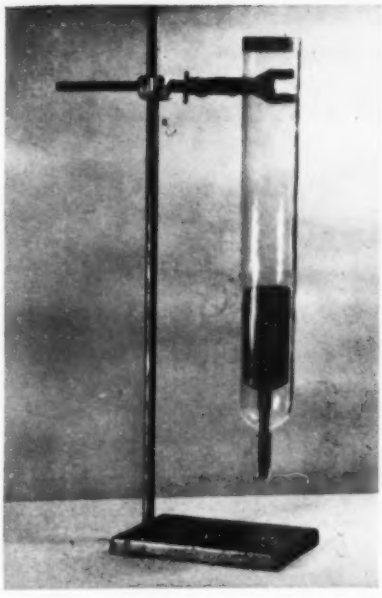

Fig. 5.—Assembled graphite crucible in position in silica furnace tube (graphite powder packing omitted).

this assembly and acting as a water jacket is a strong Perspex tube 18 in. in length by 3 in. outside diameter.

The connection between the silica tube and the head of the four stage mercury vapour diffusion pump is made by a mild steel tube of 3 in. internal diameter which has been nickel plated. The furnace head is water cooled from the outside by means of a spiral copper tube. The silica furnace tube is connected to the head by a thick neoprene rubber ring compressed against the outer wall of the tube by means of a screwed collar (Fig. 6). A similar seal is used for the water jacket, the two tubes thus being individually rendered water and vacuum tight. Let into the metal furnace head in a horizontal

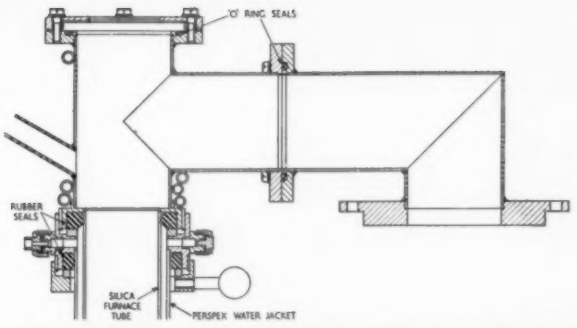

Fig. 6.—Section through furnace head showing methods of vacuum and water sealing.

position is an optically polished silica window, protected from furnace radiation and film deposition by a metal disc which, when operated from the exterior, turns and allows furnace temperature measurements to be made with an optical pyrometer. The metal head is also fitted with a McLeod gauge to measure the pressure on the high vacuum side of the equipment whilst a Pirani gauge is connected between the output side of the diffusion pump and the input of the Toepler pump.

The Speedivac 2M4 mercury vapour diffusion pump manufactured by Messrs. Edwards is a four stage metal pump, only 16 in. high, which is capable of pumping at a rate of 75 lit./sec. against high backing pressures with moderate heater input. The limiting backing pressure is 35 mm. of mercury, and the heater capacity 850 W.

Gas Collection and Analysis Unit

The gas evolved during the melting of a specimen, consisting of carbon monoxide, hydrogen and nitrogen, is passed to a combined Toepler pump and McLeod gauge, the Toepler pump being operated with an air compressor (Fig. 7). From the calibrated bulbs, the gas is circulated through a copper oxide catalyst maintained at 600° C. Here the carbon monoxide is oxidised to carbon dioxide and the hydrogen to water. The water is

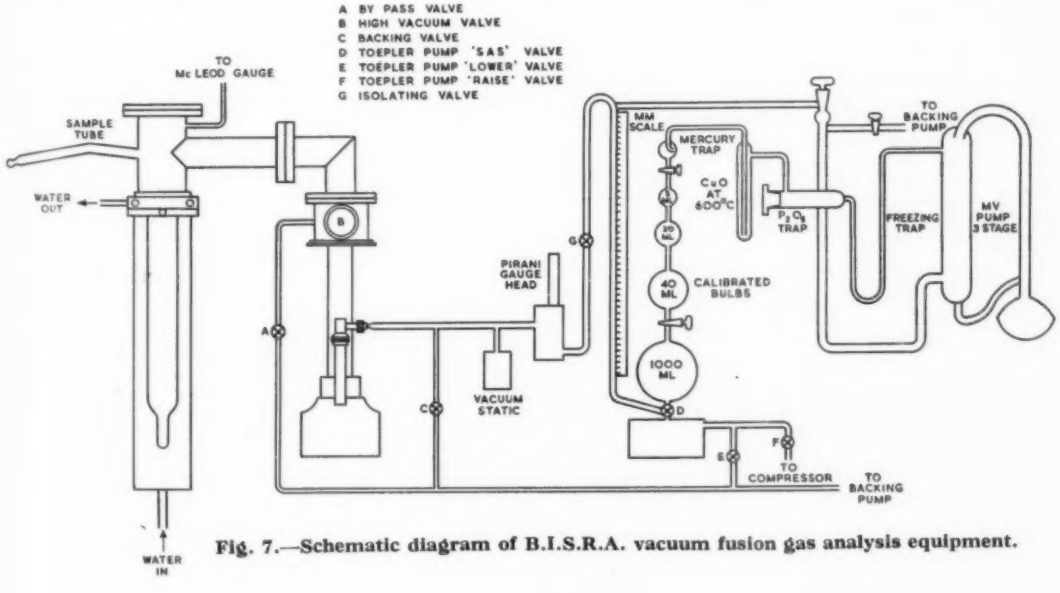

Fig. 7.—Schematic diagram of B.I.S.R.A. vacuum fusion gas analysis equipment.

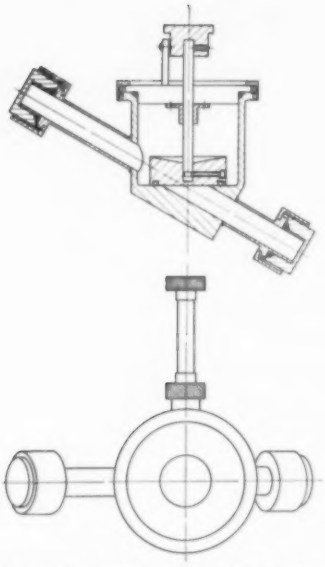

Fig. 8.—Side elevation and plan of vacuum lock attachment.

removed when the reaction products pass over a phosphorus pentoxide trap prior to entering a freezing trap. Circulation is maintained by a small three stage mercury vapour diffusion pump which returns the gas to the calibrated bulbs. When carbon dioxide is to be removed, the freezing trap is immersed in a Dewar flask containing liquid oxygen.

By measuring the gas pressure both before and after the oxidation and water absorption stage, the hydrogen content of the metal may be obtained. To determine the oxygen and nitrogen content, following upon the freezing out of the carbon dioxide, the residual nitrogen is pumped away, the carbon dioxide is allowed to expand to room temperature and the pressure again measured. Pressure differences allow the oxygen and nitrogen content of the metal to be calculated.

Operational Procedure

A mechanical means of individual charging of specimens through a vacuum look was tried, but this was not entirely successful (Figs. 8 and 9). The application of the mercury lift for charging purposes is acknowledged, but it is felt that further work on the mechanical method will yield a positive result. In the meantime, samples each weighing up to 20 g. are introduced into a sample arm from where they can be charged one by one into the furnace by means of a magnet. After preliminary evacuation by means of a rotary oil pump to a pressure of 0·05 mm. of mercury, the diffusion pump is put into operation, and when the pressure has been reduced to 10^{-4} mm., the furnace is switched on. The temperature is gradually raised to 2,400° C. and outgassing continued until a pressure of 5×10^{-5} mm. is obtained. This usually takes two to three hours. The temperature is then lowered to the operating level of 1,600–1,650° C. and the blank rate determined. Assuming that this is of the order tolerated—0·02 ml. of gas per hour, the melting procedure is carried through for each sample in turn. The ratio of "dead space" volume to Toepler pump volume is about 1 to 7½, so that three strokes of the pump will collect the bulk of the evolved gas.

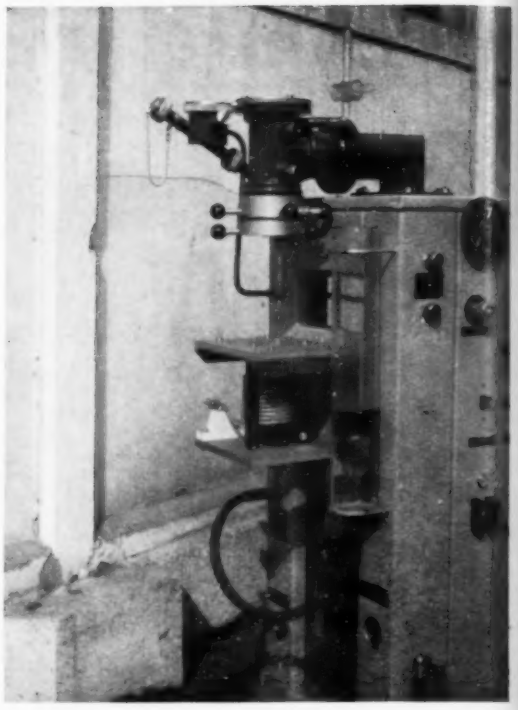

Fig. 9.—Vacuum lock attachment in position on furnace head.

Over the period of a determination, which takes 15–20 minutes, the blank amounts to approximately 0·007 ml. The "make up" of the blank is roughly 45% carbon monoxide, 45% hydrogen and 10% nitrogen. From this it will be seen that the oxygen content of the blank is equivalent to 0·0000012%—an amount which may be ignored in practice.

Conclusions

The maximum blank of 0·02 ml./hr. contrasts favourably with other reported blank rates, e.g. 0·4 ml./hr., 0·2 ml./hr. and 0·02 ml./hr. The equipment is robust and can be resited if necessary with the minimum of inconvenience. The use of rubber "O" ring seals has eliminated the necessity for greased ground glass joints, with the ever present danger of contamination and source of large blank values. The high pumping speed obtainable with the diffusion pump has minimised the possibility of the absorption of gas on the surface of freshly deposited metal films.

Future developments envisaged include the replacement of the mild steel head with one constructed from stainless steel and refinement of the vacuum lock, by which means samples at atmospheric pressure may be introduced to the apparatus under vacuum, thus allowing intermittent operation to be accomplished.

West Instrument, Ltd., makers of scientific and recording instruments for all purposes are now represented in the London, Manchester, Birmingham and West Country areas, as well as in Australia, Belgium, France, Germany, Holland, Italy, New Zealand and Spain. Details can be obtained from the Head Office at 52 Regent Street, Brighton, Sussex.